

LETTER OF TRANSMITTAL.

THE UNIVERSITY OF NEBRASKA.
AGRICULTURAL EXPERIMENT STATION.

To His Excellency, George L. Sheldon, Governor of Nebraska:

SIR: In accordance with the act of Congress approved March 2, 1887, and the act of the general assembly of the State of Nebraska approved March 31, 1887, establishing and regulating experiment stations, I have the honor herewith to submit the Twenty-first Annual Report of the Nebraska Agricultural Experiment Station.

E. A. BURNETT,
Director.

January 29, 1908.

GOVERNOR'S CERTIFICATE.

STATE OF NEBRASKA, EXECUTIVE DEPARTMENT,
LINCOLN, JANUARY 29, 1908.

Mr. E. A. Burnett, Director Nebraska Agricultural Experiment Station:

SIR: I hereby acknowledge receipt of the Twenty-first Annual Report of the Nebraska Agricultural Experiment Station.

GEORGE LAWSON SHELDON,
Governor.

THE OFFICIAL ROSTER OF THE STATION.

THE GOVERNING BOARD (THE REGENTS OF THE UNIVERSITY)

HON. CHARLES S. ALLEN, Lincoln, President.....	Term expires 1910
HON. WILLIAM G. WHITMORE, Valley.....	Term expires 1910
HON. FREDERICK H. ABBOTT, Aurora.....	Term expires 1912
HON. VICTOR G. LYFORD, Falls City.....	Term expires 1912
HON. CHARLES B. ANDERSON, Crete.....	Term expires 1914
HON. GEORGE COUPLAND, Elgin.....	Term expires 1914

J. S. DALES, Financial Secretary.*

THE EXECUTIVE COMMITTEE.

CHARLES S. ALLEN	E. BENJAMIN ANDREWS	E. A. BURNETT
------------------	---------------------	---------------

THE STATION OFFICERS.

E. A. BURNETT, B. Sc.....	Director
W. W. MARSHALL.....	Executive Clerk

THE WORKING STAFF.

H. R. SMITH, B. Sc.....	Animal Husbandry
A. T. PETERS, D. V. M.....	Animal Pathology
FREDERICK D. HEALD, Ph. D.....	Botany
E. J. ALWAY, Ph. D.....	Chemistry
A. L. HAECKER, B. Sc. A.....	Dairy Husbandry
LAWRENCE BRUNER, B. Sc.....	Entomology
E. G. MONTGOMERY, B. Sc.....	Field Crops
FRANK J. PHILLIPS, M. F.....	Forestry
ERWIN H. BARBOUR, Ph. D.....	Geology
G. R. CHATBURN, A. M.....	Highway Engineering
R. A. EMERSON, B. Sc.....	Horticulture
O. V. P. STOUT, C. E.....	Irrigation
G. A. LOVELAND, B. Sc.....	Meteorology
ALVIN KEYSER, A. M.....	Soils
W. P. SNYDER, M. S..	Superintendent Experimental Substation, No. Platte
J. H. GAIN, M. D. C.....	Associate in Animal Pathology
A. F. MAGDANZ, JR., A. B.....	Assistant in Animal Husbandry
L. B. STURDEVANT, A. M.....	Assistant in Animal Pathology
STELLA A. HARTZELL, A. M.....	Assistant in Chemistry
E. M. LITTLE, B. Sc.....	Assistant in Dairy Husbandry
MARTIN NELSON, M. S.....	Assistant in Field Crops
F. E. DENNY, A. B.....	Assistant in Horticulture
S. W. PERIN.....	Farm Superintendent

*By an act of the Legislature of the State of Nebraska approved and in effect February 15, 1899, the State Treasurer became *ex officio* custodian of the Experiment Station fund on and after July 1, 1899.

TABLE OF CONTENTS.

	PAGE
LETTER OF TRANSMITTAL	iii
GOVERNOR'S CERTIFICATE	iii
OFFICIAL ROSTER OF THE STATION.....	iv
DIRECTOR'S REVIEW—	
Experimental work	vii
Spraying apple orchards	xvii
Potato experiments	xviii
Cooperative experiments	xix
The North Platte Substation—	
Wheat	xx
Oats	xx
Barley	xxi
Rye	xxi
Corn	xxi
Alfalfa	xxi
Brome grass	xxii
Annual forage crops	xxii
Dry land farming	xxii
Alkali soils	xxiii
Tree planting	xxiii
Orchard planting	xxiii
Growing hogs	xxiii
Cattle feeding	xxiv
The Station staff	xxv
Improvements	xxv
Farmers' Institutes	xxvi
Publications	xxvii
Station mail	xxix
Acknowledgments	xxix
FINANCIAL STATEMENTS—	
Hatch fund	xxx
Adams fund	xxxi
Other Station moneys	xxxiii
State appropriations—	
Farmers' Institutes	xxxliii
Substation (North Platte).....	xxxliii

APPENDIX.

SOME TOMATO FRUIT ROTS DURING 1907, WITH TABLE OF CONTENTS....	1
A NEW FORM OF <i>Sphaeropsis</i> ON APPLES—	
<i>Sphaeropsis malorum</i>	34
The new form of <i>Sphaeropsis</i>	36
Cultural characteristics	36
Inoculations	38
Sections	41
Extent of injury.....	42
Distinctions	43
Species identity	43
Literature cited	44

	PAGE
SEED TREATMENT FOR THE SMUTS OF WINTER BARLEY—	
Introduction	45
Description of the barley smuts.....	45
The treatments carried out—	
(a) The formalin steep	49
(b) The modified formalin steep.....	50
(c) The hot-water treatment	50
(d) Corrosive sublimate steep	50
(e) Copper sulphate steep	50
Arrangement of test plats	50
Effect of treatment upon germination and vigor of growth..	51
Recommendations	53
THE MOLD OF MAPLE SYRUP—	
Introduction	54
Historical	54
Description of the fungus.....	56
Growth in cultures	57
Relation of growth to concentration of sugar.....	59
Effect of concentration of sugar on spore size.....	66
Effect of form of nitrogen on growth.....	66
Analyses of syrups	67
Literature cited	68
A ROT OF GRAPES DUE TO <i>Pestalozzia uvicola</i> SPEGAZ.....	69
A STRENGTH TEST OF HARNESS LEATHER.....	73
LOCO WEED POISONING IN HORSES—	
Introduction	74
Symptoms as hitherto described.....	74
The pastures used	76
First attempt to induce loco-eating habit.....	77
Case of Horse No. 1.....	78
Case of Horse No. 2.....	78
Loco-eating history of Horse No. 2.....	78
Symptoms of Horse No. 2.....	80
Post-mortem examination of Horse No. 2.....	92
Case of Horse No. 3.....	93
Loco-eating history of Horse No. 3.....	93
Post-mortem examination of Horse No. 3.....	96
Case of Horse No. 4.....	97
Loco-eating history of Horse No. 4.....	97
Symptoms of Horse No. 4.....	97
Post-mortem examination of Horse No. 4.....	98
Case of Horse No. 5.....	99
Case of Horse No. 6.....	100
Summary—	
Loco-eating history	101
Symptoms	102
Post-mortem examinations	105

TWENTY-FIRST ANNUAL REPORT.

EXPERIMENTAL WORK.

The work of the Experiment Station for the current year has been as follows:

The lines of investigation in the Experiment Station are of two classes: First, those which are technical and scientific in their character, endeavoring to discover scientific principles which may have a bearing on practical farm problems; second, the adaptation of scientific principles already worked out, to the practical needs of the farmer.

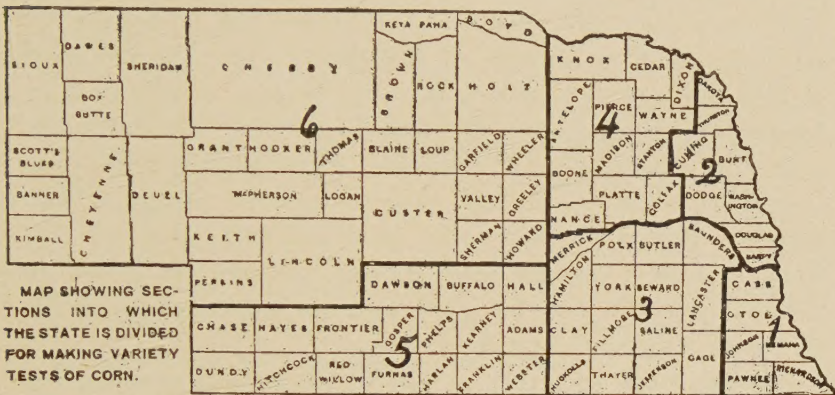
All investigations carried on under the Adams act are, according to limitations of Congress, confined to strictly scientific questions or the accumulation of knowledge which does not now exist and which when worked out may have a bearing upon practical agricultural questions. The other funds of the Experiment Station, such as the Hatch fund appropriated by the federal government and state appropriations, are available for the less technical lines of investigation which may have the most immediate and beneficial influence on the general farm practices of the state.

The work which this Station has done in the extension of the winter wheat area of the state has resulted in very greatly increased areas of wheat, carrying this extension first to the southwest, then to the northeastern section of the state, where production has increased more than 9,000,000 bushels in the last seven years, and more recently extending winter wheat production into the northwest area of the state thru the work of the Substation at North Platte, where the yields of winter wheat upon summer tilled land have exceeded the average yields of wheat in the eastern counties of the state under the methods of production in common use.

Under the Adams fund, investigations have been carried on in the bleaching of wheat flours to determine whether the processes now in use by the millers have a deleterious effect on the health of persons consuming such flours. These investigations are reported in Bulletin No. 102. The general subject of wheat flours is further being investigated to determine the cause of the strength of flour or those qualities which tend to produce a large and well-formed loaf and make the flour desirable from the standpoint of the miller. Considerable controversy exists among scientific men at the present time as to the true cause of strength in flour, and until this can be determined it is impossible to determine what qualities in wheat should be developed in order to produce the most desirable wheat from the miller's standpoint. In connection with this work the Experiment Station is developing a large number of strains or subvarieties of Turkey Red wheat with the expectation that the yield of some of these wheats will considerably exceed the yield of the Turkey Red wheat in common use and that the chemical composition of this wheat will be such as to make it the most acceptable from the miller's standpoint.

The work of the Experiment Station in promoting the corn industry of the state has been large and efficient. Within the last five years, under the stimulus and advice of the Experiment Station, more accurate and exact study of the improvement of corn has been made than in all the years which preceded. The agitation for the selection of better seed has resulted in giving very much greater attention to this important question. The discussion of soil fertility, the rotation of crops, and of tillage to conserve moisture, have all tended to modify the practice of the average farmer and very greatly to improve the methods of the men who had previously given this subject special study. This investigation has tended to unify the general opinion regarding varieties best adapted to localities and to prove by careful investigation that certain varieties were superior to others which had commonly been grown. Five years' work has been done to determine

what two varieties of corn were best adapted to each of the different corn regions of the state. The result of these investigations has shown that in the eastern section of the state, with twenty-seven men cooperating, the average yield of the best two varieties in each county for five years has been 54 bushels per acre, the average yield of all corn in the same counties being 36 bushels per acre. The selected varieties produced an average of 18 bushels per acre more than the average of the county. This is good evidence to show that if good varieties are used and the average standard of farming is brought up to that of the best farmers in each neighborhood, an average increase of 15 to 20 bushels per acre would result. The state has been divided into six



different corn districts, according to a map shown herewith. The tests of cooperative farmers assisting in this investigation have shown:

In Section 1, Reid's Yellow Dent gave best average yield for five years, 1902 to 1906 inclusive. Hogue's Yellow Dent gave next best yield. These are both yellow varieties. The two most promising white varieties were Nebraska White Prize and Silver Mine. Results obtained during the past three years, however, indicate that Chase's White Dent may be the best white variety.

In Section 2, Reid's Yellow Dent has given best yield for five years, and Hogue's Yellow Dent second best. The two best white varieties are Silver Mine and Nebraska White Prize.

In Section 3, Hogue's Yellow Dent has given best yield and Golden Row second best. Silver Mine and Chase's White Dent are to be recommended for white varieties.

In Section 4, Golden Row and Reid's Yellow Dent have given best results as yellow varieties, and Nebraska White Prize and Silver Mine as white varieties, tho in many cases the two white varieties have not matured well.

In Sections 5 and 6 we have not been able to secure sufficient information to determine certainly the varieties best adapted. A collection of native corns was made last year from forty different farmers, and the work will be considerably extended in the future. At the North Platte Station for the years 1905 and 1906, calico corn gave yields of 39.3 bushels and 52 bushels respectively, with an average of 45.6 bushels. Reid-Hogue cross yielded 39.3 and 47.8 bushels, with an average of 43.5 bushels. Improved Leaming yielded 37.1 bushels and 47.4 bushels respectively, with an average of 42.4 bushels. Silver Mine, a white corn, yielded 39.3 bushels and 52.2 bushels, with an average of 45.9 bushels. The calico corn above mentioned will probably continue to hold a leading place among the varieties grown in western Nebraska, and the other varieties mentioned are liable to change with more extensive tests.

Breeding work with corn at the central Station covering five years' investigation shows the average of such corn to be nine bushels per acre more than the check plats from which this corn originated, these check plats having been grown upon the land in the same state of fertility and with the same conditions of tillage as the corn which had been selected for increased yield and higher producing types. The final distribution of these improved varieties cannot but have a large beneficial effect upon the corn-growing industry in the regions to which they are adapted.

Under the Adams fund investigations, we are studying the relation of leaf area to the water used in the growth of the corn plant. It is proposed to determine by means of potometers the

amount of water used by different types of the corn plant, and later to determine which type of plant is best adapted to Nebraska conditions, which has the greatest yield, and which the greatest ability to withstand drought. It is believed that this investigation will determine what particular characteristics of the corn plant enable it to reach the highest development and produce the greatest yield under the conditions which exist in this state. When these facts have been determined, the development of corn having the proper characteristics will materially increase the yield per acre and have an economic bearing upon the production of the state.

An investigation of the soils of the state is in progress, to determine roughly the different soil regions of the state as indicated by the different geological formations from which these soil regions are derived. This line of investigation should be continued until accurate maps of these soil regions are available, as the character of the soil in the different regions of the state will influence the character of the agriculture which is practiced. Our neighboring states to the east are spending large sums of money at the present time in working out these soil regions for their respective states and have already found that the knowledge thus obtained has made it possible to operate the lands in the different areas more profitably than could be done without this exact knowledge regarding the constituents of which the soil is made up.

Limited experiments have been carried on to determine the influence of commercial fertilizers upon the wheat crop in the older sections of the state. These experiments so far indicate that soils which are declining in their productiveness are lacking in nitrogen, but are not lacking in the other elements of plant food necessary to a fertile soil. Nitrogen is readily supplied by the application of barnyard manure, or by seeding lands down to grass, alfalfa or clover, and permitting a rest from grain production for a period of years, after which these lands can again be used for growing grain with very greatly increased production. All

of the investigation which has been carried on relative to the management of soils points conclusively to the fact that rotation of crops is necessary to secure the largest yields and the largest profits from the land; that periods of grain growing must be interspersed with periods during which the land is in grass or leguminous crops like clover and alfalfa, and that the maintenance of the fertility of the soil in any region of high-priced land is the key to successful agriculture.

Studies in soil tillage have shown that water should be conserved or stored up in the soil when there is no crop upon the land, so that it may be used by the crop later on. Especially in the western section of the state it is impossible to depend upon the rainfall of the growing season to supply the water necessary to mature a crop. While timely rains may supply an abundance of water, there is likely to be a period during the growth of any crop when soil water is deficient. If crop production is carried into the region where it has not before been generally successful, it will be largely thru the introduction of methods which store water in the soil before the crop is sown, to assist in maturing the crop during the latter period of its growth. Since these principles apply to all agricultural regions, and since shortage of soil water is likely to occur in the regions of most abundant rainfall, it is essential that our farmers understand the principle of conserving soil water and use those methods, even in the regions of most abundant rainfall. Such methods act as an insurance in crop production and once understood can be applied to the land without largely increasing the cost of farm operations.

The relation of humus (total organic matter) in the soil to the storing up of water and plant food is one of the leading lines of investigation in the Experiment Station.

A study of beef production has been made by this Station, to determine how the crops which are grown on the ordinary farm can be utilized by cattle to produce the largest revenue. Bulletins Nos. 75, 85, 90, 93 and 100 deal with the question of eco-

nomical beef production. Two hundred and ninety-four cattle have been used in these experiments, which have conclusively shown that the character of the ration is an essential factor in economical production; that economical rations containing the food nutrients which are adapted to the use of the animals fed may be simple and may be grown entirely upon a Nebraska farm. Roughly speaking, the essential point in food nutrients is that there shall be a proper relation between what are known as the protein constituents of the food and the carbohydrate and fat constituents of the food; in other words, between the albuminoid material in the food and the starches, sugar, fat and crude fiber in the food. These proportions do not need to be determined with mathematical accuracy, but can be determined with sufficient accuracy to give economical results by any farmer who understands something of the nature and character of these different foods. For example, there is a certain class of foods grown on the farm which will supply the protein requirements in fattening cattle. These foods are, first, alfalfa hay; second, clover hay; followed by oats and bran as useful but not so economical foods at their present prices. This makes the range of protein foods grown on the Nebraska farm extremely narrow, and, when these foods cannot be supplied from the farm, experiments have shown that it is economical to purchase in the markets commercial foods which supply these protein requirements. The commercial foods most commonly used are linseed-meal, cottonseed-meal, and possibly those protein foods which are the by-products of the starch factory. All of the experiments of our Station have shown that protein foods can be produced upon the farm in the form of alfalfa hay at about half the cost of such food constituents when purchased in the form of commercial foods. The farmer who takes advantage of this knowledge and grows his protein upon the farm accomplishes the double result of making large profits upon his cattle feeding operations and of very greatly increasing the productiveness of his soil by the same operation.

It has been shown by experiments that more protein nutrients are supplied by alfalfa hay when it is used as the entire roughness of feeding steers than is necessary for their use, and that it is possible to utilize prairie hay, corn stover and unhusked corn which has been shocked at the proper time so as to make these forms of roughness very much more valuable than they could be made without the use of alfalfa hay in feeding operations.

It has been shown that the use of alfalfa hay and corn-stover fed in connection with shelled corn will produce a liberal profit in beef production where the use of prairie hay and shelled corn has given an actual loss in feeding operations.

It has been shown that younger cattle, especially calves and yearlings, are more dependent upon protein nutrients found in alfalfa hay or linseed- or cottonseed-meal than older cattle, and that the farmer, when he attempts to feed calves or yearling steers, will find it more necessary to maintain the proper balance between protein and nonprotein food constituents than in feeding older and mature cattle.

In fattening pigs upon corn as the principal ration, it has been found that the use of tankage, a by-product of the packing house, has increased the rate of gain and decreased the cost of production where the percentage of tankage fed was about five per cent of the total ration; that a larger per cent of tankage did not greatly increase the rate of gain, and in some instances did increase the cost of gains to a point above the cost where corn alone was fed. These experiments show, as do the experiments with cattle, that there should be a certain relation between the protein and nonprotein constituents of the food of any animal, and that it is as possible to increase these protein constituents beyond the point of profitable production as it is to limit them below the point of profitable production. In other words, it is necessary to know with some approximation what the requirement of the animal is, and to supply these foods in the proportion which is needed by the animal fed. Pigs which are fed upon alfalfa pasture

are not so dependent upon protein in other food constituents as those which do not have alfalfa pasture. The tests at the central Station, however, indicate that alfalfa pasture does not furnish a sufficient amount of protein for economical production when corn makes the balance of the ration, but that mixed grains with alfalfa pasture overcome the necessity for feeding tankage when they can be supplied at a lower cost. The results of experiments at the western Station have indicated that corn and alfalfa hay or such mixed grains as corn, barley, speltz, and alfalfa hay furnish cheaper protein nutrients than were supplied in tankage.

Experiments are in progress which are of very great interest to the breeder of pure-bred stock, indicating that the strength of bone in pigs may be very materially increased by the use of tankage, of ground bone, or of skim-milk fed with grain in growing pigs. Three years' work has been done on this problem and the results have uniformly shown a marked increase in the strength of bone where tankage or ground bone has been fed. This information is valuable because the character of the feed used in pork production tends strongly to produce a bone of low tensile strength and a small percentage of mineral matter, while the heavy weights developed in the young pig tend to produce animals which do not stand properly on their feet. The experiments above mentioned indicate that by proper methods of feeding and care in the selection of individuals for breeding purposes the tendency toward bad feet and legs may largely be overcome.

Experiments at the western Station reported in Bulletin No. 99 show that even in western Nebraska where alfalfa is abundant and grain of moderate price, liberal grain rations produce larger profit and more economical results than are secured by growing hogs largely upon alfalfa pasture. These experiments indicate that where alfalfa hay is fed and corn is valued at 35 cents per bushel, barley is worth about 24 cents per bushel and emmer about 19 cents per bushel, four bushels of barley being equal in value to five bushels of emmer. It is not probable that

a second experiment would exactly verify these figures, altho we should expect it to reasonably approximate these results.

The work of the Experiment Station in the care and management of dairy cattle has shown that the value of the individual members of the herd can only be determined by individual milk and butter fat records. Such records will show great variation in the value of the different animals and will serve as a guide in the building up of an efficient herd.

Cows vary from year to year in their butter fat production. The good cows in this herd have been inclined to give large yields year after year, while the poor ones have always been relatively low. It has been found that as a rule the variation in milk flow in individual cows from year to year is due to length of lactation period and rest before freshening. A long period favors a large milk production. The cows which have given large annual yields have all been persistent milkers and have continued milking to within four or six weeks of the next calving time.

A study of the cost of butter fat production has shown that the amount of milk and butter fat produced depends upon the dairy capacity of the animal and the amount and quality of the ration used. Cows of a decided dairy type will return the greatest profit in milk and butter when fed to their full capacity. The average cost of feeding a dairy cow as shown by these records is about \$30 per year, and the total value of butter fat of the Station herd is about \$70 annually per cow: leaving an average of about \$40 for labor and profit in addition to the value of the skim-milk and the value of the calf.

With the prices for forage and grain which have prevailed at the Experiment Station for the last four years, the cost of butter production can be reduced about 20 per cent by the use of silage as a part of the ration. This result is obtained by reducing the cost of feed and by materially increasing the average yield of butter for each cow thru the use of succulent feed during the winter season. The people of this state have been slow to adopt the silo in the production of butter, from a feeling that the silo

does not fit into their method of dairying and that the original cost is too high. It has been found at the Station that even with the use of alfalfa hay, which is a most excellent ration for butter production, the cost of butter could be still further lowered by the use of silage as a part of the ration. The Station is firmly convinced that all dairymen milking twenty-five or more cows can profitably incur the expense of a silo under such conditions as now exist in eastern Nebraska.

The Experiment Station has published a bulletin on "The Fat Testing of Cream," which is being used as a standard method by the Dairy and Food Commissioner of the state.

SPRAYING APPLE ORCHARDS.

During the summer of 1906, spraying demonstrations were conducted in six counties in Nebraska, the United States Department of Agriculture cooperating, the purpose of the work being to control the apple scab and codling-moth and to determine whether the advantages of such spraying would pay the cost incurred. These demonstrations were continued during the summer of 1907, with the result that a very superior quality of fruit was produced upon the trees which were sprayed. Records made at the end of the season from the entire crop of 37 sprayed trees and 39 unsprayed ones in different orchards, including observations on more than 110,000 fruits, showed 22 per cent of wormy apples on the sprayed trees and 46 per cent on the unsprayed ones. Of the sprayed fruits 6 per cent and of the unsprayed fruits 38 per cent were scabby.

During the fall, the foliage of the sprayed trees was much healthier than that of the unsprayed ones. In many cases from 50 per cent to 75 per cent of the foliage of unsprayed trees was on the ground early in October and in some instances the trees were almost completely defoliated at that time. At the same time the leaves of the sprayed trees were bright green and comparatively free from fungus diseases.

The crop was gathered from 205 sprayed trees and 71 un-

sprayed trees. The average yield of the sprayed trees was 8.4 bushels per tree and of the unsprayed trees 6.6 bushels per tree. When sorted into merchantable and unmerchantable fruit, 8 per cent of the sprayed fruit and 23 per cent of the unsprayed fruit were unmerchantable. The total value per tree of the unsprayed fruit was \$0.80 and of the sprayed fruit \$1.87. The cost of spraying was 21 cents per tree. The profit of the sprayed trees over the unsprayed trees was 86 cents per tree.

POTATO EXPERIMENTS.

Experiments to determine the effect of mulching potatoes as against cultivation have been carried on for a number of years. Potatoes grown under a mulch have been of poorer quality for table purposes than those grown under cultivation, but have been superior for seed purposes. Medium-sized seed pieces, about one-quarter of a tuber, are superior to smaller sized pieces when planted in hills so that the amount of seed equals from 15 to 20 bushels per acre. Potatoes planted 4 inches deep gave larger yields than those planted either shallower or deeper than 4 inches. The results of this work are reported in Bulletin 97.

The Station has recently investigated the subject of loco poisoning in horses and expects to present a detailed report of its work in the appendix to this Report.

The study of cornstalk disease has been systematically carried on in three counties of the state, in an effort to determine the prevalence of the disease, the methods of treatment, if any, which were successful in lessening the loss, etc. The result of this work is reported in Press Bulletin No. 27. No information tending to prevent the loss of cattle turned upon stalk fields has been developed in this investigation.

An investigation of the seed of cheat, meadow fescue, and brome grass by the Station has shown that a large amount of cheat seed is annually sold as either brome grass or meadow fescue by persons who ignorantly or otherwise have misrepresented the variety of seed for sale. Press Bulletin 25 deals with this subject. The Experiment Station is establishing, in

cooperation with the United States Department of Agriculture, a seed testing laboratory, where all samples of grass seed and other seeds sent to the Station will be examined free of cost. The per cent and quality of impurities in seed samples will be reported, as well as the per cent of germination.

The Station has recently investigated a new disease which has been somewhat prevalent in Nebraska and a number of other states during the last few years, known as the bud-rot of carnations. This disease has been proved by the Station to be due to a definite species of fungus, *Sporotrichum anthophilum* Peck, which has, associated with it, a new species of mite, *Pediculoides dianthophilus* Wolcott, as a constant accompaniment. The disease affects the buds of carnations in various stages of maturity and rots the petals and other flower parts, interfering with the normal opening of the flower. The disease is successfully treated by special care to remove from the greenhouse all material favoring its propagation, by keeping the moisture down to the minimum necessary for the healthy growth of the plants, and by picking off and burning all the diseased portions of any plant. Benches should be gone over at least every other day until the disease is thoroly under control. The results of this investigation are published in Bulletin 103.

COOPERATIVE EXPERIMENTS.

Cooperative experiments are in progress with farmers of the state in testing varieties of corn adapted to different regions, in extending the winter wheat area of the state, in introducing winter barley to determine its hardiness and production, and in spraying demonstrations with apple orchards.

In cooperation with the federal Department of Agriculture, experiments are in progress to improve the quality and production of hard winter wheats, to introduce new crops into the region, to control apple scab and codling-moth by spraying, to study the effect of tillage and rotations on crop production, to study alkali-resistant crops, testing varieties of sweet corn, and in the prosecution of the plant disease survey of the state.

THE NORTH PLATTE SUBSTATION.

WHEAT.—Systematic experiments have been carried on in the growth of winter wheat, with the purpose of extending the winter wheat area still farther to the west and north. Most of the winter wheat grown on the Station farm to date has been upon summer tilled land. In the summer of 1906, Turkey Red wheat produced from 31 bushels to 44 bushels per acre. The yield for the year 1907 upon high table-land which had been summer tilled varied from 56 bushels to 60 bushels per acre. Nine acres of land on the bench or second bottom about 200 feet lower than the high table yielded about 30 bushels of rye in 1906, was plowed and sown to wheat, and produced 41 bushels per acre in 1907. It would seem that the essential thing in successfully growing winter wheat in Lincoln County and farther west is to secure a good seed bed with sufficient moisture to give a good fall growth. Spring weather conditions will, of course, have much influence on the crop, but if sufficient moisture has been stored in the soil in advance of sowing the crop, this acts as an insurance against winter and spring drought. In the region of the Substation farm, wheat sown about September 15th upon land with plenty of moisture present has secured a sufficiently heavy fall growth.

While winter wheat has been phenomenally successful at the Substation, the durum wheats have given satisfactory yields and have greatly extended the wheat area of western Nebraska and eastern Colorado and Wyoming. The yields of durum wheat at the Station farm have averaged about 18 bushels per acre for the three years of 1904, 1905, and 1906, while local wheat for the same years on the same land yielded but 7.2 bushels. In 1907 the yields were, for durum, 17 to 33 bushels, and for local spring wheat about the same. The cold, freezing weather in spring was unfavorable to the durum varieties.

OATS.—The oat crop has given fair yields where early varieties have been raised. The Kherson oat has taken the lead at this Station, tho two other varieties have yielded nearly as well. The yield of Kherson oats for three seasons, 1904, 1905, 1906, has been

from 24 bushels to 52 bushels, of Texas Red oats for the same period from 29 bushels to 43 bushels, of Sixty Day oats for the same period from 20 bushels to 48 bushels.

BARLEY.—Barley has been quite universally successful as a spring grain, and emmer fairly successful.

RYE.—Rye has given good yields and has furnished a most excellent pasture for brood sows in winter and in early spring before alfalfa is ready to pasture. It has then gone on and produced a fair yield of grain if not pastured too heavily in winter.

CORN.—Experiments with corn have shown that those varieties which have been grown in the region are generally best adapted to use, even tho they have not been bred and selected for the highest types. Only the earlier of the introduced varieties will ripen at this altitude. In 1905 the five leading varieties produced from 36 bushels to 39 bushels per acre. In 1906 the five leading varieties produced from 47 bushels to 52 bushels. Three years' work would indicate that calico corn is the safest variety for the general farmer to raise in this region. There are doubtless several other satisfactory varieties of the smaller sort. Large varieties, like Hogue's Yellow Dent, Silver Mine, and Hogue-Reid cross, have ripened in favorable seasons, but cannot be considered safe varieties for this region.

Careful tests are in progress with wheat, oats, barley, rye and corn to determine the most desirable rate of seeding, time of seeding, preparation of the seed bed, cultivation, and effect of manures on the yield and quality of crop.

ALFALFA.—About 100 acres of alfalfa is growing on the Substation farm, partly on the table and partly on the bench land or second bottom land. The alfalfa on the bench has produced three crops of hay each year and in addition has pastured about eight pigs per acre thruout the growing season, giving yields not far different from the high-priced lands in eastern Nebraska. The alfalfa on the table-land has varied greatly in yield, dependent on seasonable rains. It has always produced one good crop of about one ton of hay per acre, and a second crop, not so

heavy, some time during the season. When rainfall has been abundant in July, this second crop has come on early and made a good yield, but where the rainfall has been scant in July and following months the second crop has been very light, showing evidence that there was little or no reserve moisture in the soil available for the growth of the plant altho there was sufficient to keep the plant alive until moisture for further growth was supplied. No difficulty has been experienced in getting a stand of alfalfa by sowing at the time the spring rains begin on land thoroly prepared. The Station hopes to produce alfalfa seed on the table-lands and thus introduce a very profitable crop for this region.

BROME GRASS.—The Substation has about thirty acres of brome grass growing and has found it to be a valuable grass, standing climatic conditions perfectly and making a good growth. It has not yet been largely used for pasture, the purpose for which it has proved best adapted in other localities.

ANNUAL FORAGE CROPS.—Annual forage crops like cane and Kafir corn have given abundant yield. When sown thick with a press drill, they make the finest and best quality of hay, but produce more seed and somewhat better growth in dry weather when planted in double drills with about 36-inch spaces between the double rows and cultivated like corn. Yields of dry forage from cane have varied from about two tons per acre to as high as six or seven tons in the season of 1907. Limited experiments have indicated that Kafir corn is more palatable for cattle than cane.

DRY LAND FARMING.—The experiments in dry land farming are carried on by means of 93 tenth-acre plats on table-land. The work consists of rotations, methods of tillage, cultivation and manuring, in growing wheat, oats, barley, corn, and cane. In connection with this work accurate records are kept of climatic conditions—precipitation, air and soil moisture and temperature, evaporation, etc., the United States Department of Agriculture cooperating.

ALKALI SOILS.—The work in alkali investigations covers 63 tenth-acre plats on a 5-acre tract of land leased by the United States Department of Agriculture. The objects sought are the determination of the relative resistance to alkali of various grain and forage crops, the development by selection of greater resistance to alkali in these, the effect of a corrective such as gypsum, and the effect of cultivation and of manure in preventing the injurious effect of alkali, the United States Department of Agriculture cooperating.

TREE PLANTING.—The work in growing trees embraces tests of varieties, spacing, mixtures, pruning and cultivation. Ten acres are being planted on "bench" land, ten acres on "table"-land and five acres in canyons, the United States Department of Agriculture cooperating.

ORCHARD PLANTING.—In the spring of 1907 about 100 fruit trees were planted of hardy varieties of apple, peach, plum and cherry. These trees are being given thoro cultivation to determine their hardiness, production and adaptability to the western regions of the state. It is proposed in 1908 to plant a number of hardy ornamental trees and shrubs to determine their suitability for planting on western farms.

GROWING HOGS.—Experiments in growing hogs on alfalfa and the grain commonly produced in the region have been in progress since the establishment of the Station. It has been shown that a light grain ration is not most economical for growing pigs unless under peculiar circumstances where alfalfa is abundant and grain very high priced and where the market conditions favor holding the hogs.

It seems probable that two or more pounds of corn daily for each hundred pounds weight of hogs is more profitable than a lighter ration. A heavier ration is desirable for the finishing period, probably between three pounds daily per hundred and a full grain ration.

Mature animals, like brood sows, after weaning pigs will gain about one-half pound per day on alfalfa without grain.

To fattening hogs that have access to alfalfa hay, corn at 35 cents, barley at 24 cents, and emmer at 19 cents per bushel have given about equal results.

It has been shown that the cost per pound of gain is not a reliable criterion of profit. A cheap gain may be so slow as to be unprofitable. Time, labor, investment and risk should be considered when reckoning profits.

Alfalfa in almost any form may be fed with profit to hogs so long as it does not make too large a proportion of the ration. When cut and fed as one-quarter of the ration with ground corn, it materially reduced the cost of gains and increased the profits.

CATTLE FEEDING.—One test has been made to determine the most economical rations in wintering cattle, taking the calf at weaning time and growing him until he is past two years old and ready for the feed lot. Five lots of calves were selected in the fall of 1905 and fed, Lot 1, alfalfa hay; Lot 2, prairie hay; Lot 3, cane; Lot 4, alfalfa and prairie hay; Lot 5, alfalfa and cane. Two pounds of grain was fed daily to each calf during the first winter. The gains made by the calves fed alfalfa hay, or alfalfa and either prairie hay or cane, were not far from 140 pounds each in the four months. The gains on alfalfa hay were 76 pounds and on cane 46 pounds for the same time. The summer gains following did not equalize these differences, so that the lots did not go into the second winter with even weights. No grain was fed the second winter, and the lots were changed so that those receiving the poorest ration the first winter should receive the best ration the second winter. Again the second winter the large and the cheap gains were made on alfalfa hay either alone or combined with prairie hay or cane. Prairie hay and cane both gave a loss of weight during the winter and reduced the profit on cattle. Bulletin 105, or Substation Bulletin No. 3, will report this experiment.

This test is being repeated at the present time, with one lot added to test the efficiency of prairie hay and cane as compared with the rations previously fed.

To continue this study of the effect of alfalfa on the growth of animals, thirty weanling colts have been purchased and put on feed, some to be grown entirely on alfalfa hay and alfalfa pasture, others on alfalfa hay and prairie pasture, and still others on prairie hay and prairie pasture, to determine the effect of alfalfa on the weight and the quality of the horses at maturity.

THE STATION STAFF.

Within the past year the following changes in the Station staff have taken place:

Professor F. G. Miller has resigned as Forester, and Professor F. J. Phillips has been employed, beginning September 1, 1907.

Mr. E. M. Little has been added to the staff as Assistant in Dairying.

Miss Stella A. Hartzell has been made Assistant in Chemistry.

IMPROVEMENTS.

The last Legislature appropriated \$100,000 for improvements at the University farm. This money is largely used for the development of agricultural education, but the Experiment Station benefits largely from the buildings and the equipment made available under this appropriation. A new heating plant has been completed, with two 350 horse power high pressure boilers, and all buildings on the University farm requiring heat have been connected with this new system. A judging pavilion, offering facilities for judging live stock and grain, is approaching completion and will furnish two stock judging pavilions, one large class room for agricultural work, a seed judging laboratory, and a large seed room for the storage of grains to be used for instructional and experimental work.

The Woman's Building has been practically completed for the use of the Department of Home Economics, furnishing dormitory facilities for sixty girls and class room and laboratory facilities for the School of Home Economics.

A machine shed has been built to house the farm tools, and

other minor improvements have been made, such as bringing power from the University campus to use at the University farm. A greenhouse and potting rooms have been erected by the State Botanist and State Entomologist on the Station farm, out of special appropriations to investigate plant diseases and insect pests, under the State Insect Pest and Plant Disease Bureau established by the last Legislature. The Department of Entomology in the Experiment Station has been furnished quarters at the University farm. A milking machine has been purchased and put in operation to determine its utility for the practical dairyman.

At the Substation, since April, 1907, the following improvements have been made at approximately the cost named: Seed house and soil laboratory, \$2,200; Herdsman's cottage, \$1,300; cattle barn with elevator and grinder, \$2,800; machine shed for farm tools, \$500; heating, plumbing and gas at Superintendent's house and soil laboratory, \$900; water system at central plant, \$400; water system at west plant, \$425; 20-horse gasoline engine and freight, \$800; 4-horse gasoline engine and freight, \$260; Huber threshing machine, \$735; fencing, posts and labor for same, \$1,000; approximate total cost, \$11,320.

FARMERS' INSTITUTES.

Several members of the Experiment Station staff have assisted in Farmers' Institute work during the year. One hundred and thirty-six Institutes were held during the year closing June 30, 1907, and one hundred and seventy-five Institutes are scheduled for the current year. Ten thousand dollars per annum was appropriated by the last Legislature for the biennium beginning April 1, 1907.

Various agricultural societies meet at the University each year, under the name of Organized Agriculture, the following societies participating: The Association of Agricultural Students, the State Veterinary Medical Association, the Poland-China Breeders' Association, the Duroc-Jersey Breeders' Asso-

ciation, the State Board of Agriculture, the Dairymen's Association, State Horticultural Society, State Poultry Association, State Bee-Keepers' Association, State Swine Breeders' Association, Women's Department of Organized Agriculture, Park and Forestry Association, Improved Live Stock Breeders' Association, Boys' and Girls' Agricultural Associations, Corn Improvers' Association, Red Polled Breeders' Association, Farmers' Institute Convention, Aberdeen-Angus Breeders' Association, Short-horn Breeders' Association.

PUBLICATIONS.

Bulletins giving the result of investigation in the Experiment Station are published in editions of from 20,000 to 25,000 each and are distributed free of charge to any resident of the state making application. There is at the present time a regular mailing list within the state of about 13,600 names. These are continually being added to, and it is desired that all farmers who are interested in the publications of this Station should ask to be placed upon this regular mailing list. The publications of the Station since those named in the last Annual Report are as follows:

Twentieth Annual Report. Presented to the Governor February 1, 1907. 5,000 copies.

Bulletin No. 95 (Substation Bulletin No. 1) (Vol. XIX, Art. II). Crop Production in Western Nebraska. Report of Experimental Substation, North Platte, Nebr. By W. P. Snyder, Superintendent, and E. A. Burnett, Director. Distributed March 18, 1907. 25,000 copies.

Bulletin No. 96 (Vol. XIX, Art. III). Some Insects Injurious to Wheat During 1905-1906. By Lawrence Bruner and Myron H. Swenk. Distributed March 18, 1907. 20,000 copies.

Bulletin No. 97 (Vol. XIX, Art. IV). Potato Experiments. By R. A. Emerson. Distributed April 13, 1907. 20,000 copies.

Bulletin No. 98 (Vol. XIX, Art. V). Spraying Demonstrations in Nebraska Apple Orchards. By R. A. Emerson. Distributed April 16, 1907. 20,000 copies.

xxviii *Agricultural Experiment Station of Nebraska.*

Bulletin No. 99 (Substation Bulletin No. 2) (Vol. XIX, Art. VI). Growing Hogs in Western Nebraska. Report of Experimental Substation, North Platte, Nebr. By W. P. Snyder, Superintendent, and E. A. Burnett, Director. Distributed June, 1907. 30,000 copies.

Bulletin No. 100 (Vol. XX, Art. I). Economical Rations in Beef Production. By H. R. Smith. Distributed September 11, 1907. 25,000 copies.

Bulletin No. 101 (Vol. XX, Art. II). Part I, Dairy Herd Record for Ten Years; Part II, Cost of Butter Fat Production. By A. L. Haecker. Distributed November 18, 1907. 20,000 copies.

Bulletin No. 102 (Vol. XX, Art. III). The Effect of Bleaching upon the Quality of Wheat Flour. By F. J. Alway. Distributed October 23, 1907. 5,000 copies.

Bulletin No. 103 (Vol. XX, Art. IV). The Bud-Rot of Carnations, by F. D. Heald; A Mite Accompanying the Bud-Rot of Carnations, by Robert H. Wolcott. Submitted for publication October 15, 1907. Distributed January 10, 1908. 5,000 copies.

Bulletin No. 104 (Vol. XX, Art. V). Part I, Cultivation of Small Grains; Part II, The Use of the Fanning Mill for Selecting Seed Wheat and Seed Oats. By E. G. Montgomery. 5,000 copies.

Bulletin No. 105 (Substation Bulletin No. 3) (Vol. XX, Art. VI). Growing Cattle in Western Nebraska. Report of Experimental Substation, North Platte, Nebr. By W. P. Snyder, Superintendent, and E. A. Burnett, Director. 25,000 copies.

Press Bulletin No. 24. The Bleaching of Wheat Flour. By F. J. Alway. Distributed February 20, 1907. 3,000 copies.

Press Bulletin No. 25. The Seed of Cheat, Meadow Fescue and Brome Grass. By F. D. Heald. Distributed February 20, 1907. 20,000 copies.

Press Bulletin No. 26. The Fat Testing of Cream. By A. L. Haecker and E. M. Little. Distributed July 18, 1907. 5,000 copies.

Press Bulletin No. 27. Losses from Cornstalk Disease in Cus-

ter County, Nebraska, During the Winter of 1906-1907. By F. J. Alway and A. T. Peters. Distributed January 23, 1908. 20,000 copies. •

One hundred and ninety-eight thousand bulletins and annual reports were printed for distribution by the Experiment Station during the year ending December 31, 1907. These publications represented 6,092,000 printed pages.

STATION MAIL.

Mail was received and sent out from the Experiment Station office during the year 1907 as follows:

Received—

First Class.

23,160 letters.

4,806 postals.

Second Class.

3,466 lbs.

Third Class.

1,461 lbs.

Fourth Class.

174 lbs.

Sent—

First Class.

25,285 letters.

14,868 postals.

Second Class.

703 lbs.

Third Class.

1,010 pounds.

Fourth Class.

112 lbs.

Free List—

16,370 lbs. regular bulletins.

1,365 lbs. press bulletins.

ACKNOWLEDGMENTS.

The agricultural press, especially those papers located within the state, have shown their appreciation of the work of the Experiment Station by giving liberal space to the experimental work reported and in every way facilitating the extension of useful agricultural knowledge.

We are indebted to the Thirtieth Session of the Nebraska Legislature for its appreciation of the work of the Experiment Station, as expressed by increased appropriations for the experimental work at the North Platte Station and for the further equipment and maintenance of all the agricultural work in the University.

THE AGRICULTURAL EXPERIMENT STATION OF NEBRASKA

FINANCIAL STATEMENT

RECEIPTS

Received by the state treasurer from the treasurer
of the United States, installment for the fiscal
year ended June 30, 1907, under the act of Con-
gress approved March 2, 1887 (Hatch fund).....\$15,000 00

EXPENDITURES

Salaries	\$9,431 04	
Labor	1,316 54	
Publications	2,232 14	
Postage and stationery.....	374 69	
Freight and express.....	52 08	
Chemical supplies	71 38	
Seeds, plants and sundry supplies.....	329 04	
Feeding stuffs	404 15	
Tools, implements and machinery.....	62 80	
Furniture and fixtures.....	183 06	
Scientific apparatus	310 28	
Traveling expenses	217 80	
Contingent expenses	15 00	
	\$15,000 00	\$15,000 00

RECEI. TS

Received by the state treasurer from the treasurer
of the United States, installment for the fiscal
year ended June 30, 1907, under supplemental act
of Congress approved March 16, 1906 (Adams
fund) \$7,000 00

EXPENDITURES

Salaries	\$5,307 82	
Labor	102 63	
Postage and stationery.....	78 90	
Freight and express.....	154 49	
Chemical supplies	238 73	
Seeds, plants and sundry supplies.....	194 72	
Fertilizers	134 84	
Feeding stuffs	163 75	
Tools, implements and machinery.....	35 80	
Furniture and fixtures.....	45 00	
Scientific apparatus	303 96	
Traveling expenses	239 36	
	\$7,000 00	\$7,000 00

SUPPLEMENTAL STATEMENT

RECEIPTS

Moneys received by the state treasurer from other sources than the United States, for the use and benefit of the Experiment Station and Substation, for the year ended July 31, 1907.

Balance July 31, 1906	\$6,749 64
Sales of stock, produce, etc.....	18,080 47

EXPENDITURES

Salaries	\$2,415 21
Labor	2,551 40
Postage and stationery.....	440 90
Freight and express.....	449 03
Chemical supplies	17 26
Seeds, plants and sundry supplies.....	1,616 20
Feeding stuffs	5,574 01
Library	11 54
Tools, implements and machinery.....	906 41
Furniture and fixtures.....	57 50
Scientific apparatus	884 42
Live stock	1,746 44
Traveling expenses	517 69
Buildings and land.....	2,337 73
Balance, July 31, 1907.....	5,304 37
	\$24,830 11 \$24,830 11

STATE APPROPRIATIONS

FARMERS' INSTITUTES

Balance November 30, 1906, of state general fund appropriation	\$5,368 16	
State general fund appropriation of 1907 for the two years ending March 31, 1909.....	20,000 00	
Expenditures to November 30, 1907, for superintendence, clerical services, labor, lecturers' service and expenses, printing, general supplies.....		\$7,451 61
Appropriation balance November 30, 1907.....		17,916 55
	\$25,368 16	\$25,368 16

SUBSTATION (North Platte)

State general fund appropriation of 1907, for the two years ending March 31, 1909.....	\$25,000 00	
Expenditures to November 30, 1907, for superintendence, labor, live stock, feed, seeds, tools, machinery, general supplies, and permanent improvements		\$16,162 10
Appropriation balance November 30, 1907.....		8,837 90
	\$25,000 00	\$25,000 00

J. S. DALES,
Financial Secretary.

LINCOLN, NEBR.,
December 18, 1907.

SOME TOMATO FRUIT ROTS DURING 1907.

BY VENUS WORRELL POOL.

CONTENTS.

	PAGE		PAGE
Introduction	3	Fungus characters.....	11
"Black-Rot" (<i>Alternaria fascicu-</i>		Appressoria	12
<i>lata</i> (C&E) Jones & Grout)—		Isolations and inoculations.	13
Observed symptoms.....	3	Cultural characters	14
Isolations and inoculations	4	<i>Fusarium</i> sp.—	
Description of the fungus..	4	Symptoms	15
Historical etiology.....	5	Isolations and inoculations.	15
Cultural characters.....	6	Description of the fungus..	16
<i>Rhizoctonia</i> on the Tomato fruit—		Historical	17
History	6	Cultural characters.....	17
Symptoms	7	<i>Fusarium solani</i> Mart.—	
Isolations and inoculations	7	Symptoms	17
Vegetative characters of the		Isolations and inoculations.	18
fungus	8	Description of the fungus..	18
Cultural characters	8	Historical etiology	18
"Ripe Rot" or Anthracnose of the		Cultural characters.....	19
Tomato—		Prevalence of the Rots.....	19
Symptoms	9	Preventive Measures.....	19
Historical etiology.....	10	Bibliography	21
		Description of Plates.....	21-23

SOME TOMATO FRUIT ROTS DURING 1907.*

BY VENUS WORRELL POOL.†

INTRODUCTION.

Various diseases of the tomato (*Lycopersicum esculentum*) have long been known and described. Altho many common fungi, no doubt, have the power of rotting the overripe fruit, the number is still limited which are able to grow upon the green or just ripening.

The fungi which are herein described were studied during the summer of 1907. No entirely unknown organisms were found, but several new characters of those which are more or less familiar have been observed which it might be well to add to the facts already known of these fruit rots.

The varieties of tomatoes which were used in the inoculations were the "Dwarf Champion," "Stone" and a special called "Wonder Magnus" which was one of the potato-leaved varieties. The "Dwarf Champion" as a rule did not yield so readily as the others to the rotting organisms, even under laboratory conditions.

"BLACK ROT."

Alternaria fasciculata (C&E) Jones & Grout.

OBSERVED SYMPTOMS.

The ripe fruit examined had the diseased spot at the blossom end, slightly wrinkled and dark brown to almost black in color. The collapsed flattened area extended almost across the upper surface of the fruit. (Pl. I, fig. 4.) The underlying tissues of

* Submitted as a thesis for the degree of Master of Arts, University of Nebraska, 1908.

† Assistant in Plant Pathology.

the older portions were extremely hardened in places, the intervening cavities being filled with fluffy fungus mycelium. A microscopical examination of the tissues revealed a dense formation of very dark, almost black hyphae in the older areas, while brownish colored filaments extended into the surrounding healthy tissues.

Sections made of such tissue taken from artificially infected spots revealed something of the nature of the pathological condition. The tough, hard portions are made up of a compact aggregate of swollen, almost spherical cells; some of these are rather thick walled, densely pigmented and stand out in bold relief in the midst of the surrounding brown colored ones. (Pl. II, fig. 7.) The transition from this portion to the neighboring cavity (Pl. II, fig. 6), filled with a lightly woven mass of ordinary filaments, is very abrupt. No cellular structure is distinguishable, such structure being found only in the lately rotted areas.

ISOLATIONS AND INOCULATIONS.

Glucose agar planted plate cultures made from portions of the diseased tissue, resulted in a perfectly pure growth of an *Alternaria*. Inoculations were made from the cultures obtained in this way. Five days after infection had taken place in the ripe fruit, the rotted area measured one-half inch in diameter. In ten days to two weeks the ripe tomatoes were rotted and collapsed thru one-third their entire extent. The tissue was hard, leathery and blackened, resembling the original in every particular.

No change or growth took place in the green fruit.

Glucose agar planted plate cultures made from the tissue rotted by the artificial inoculation of the fungus, produced pure cultures which were identical with the first isolations. (Pl. III, fig. 9.)

DESCRIPTION OF THE FUNGUS.

Fertile hyphae, at first hyaline to light brown, later becoming dark brown to almost black. Sterile filaments always lighter

in color than the fertile. Conidiophores when mature, dark as the conidia and measure 30-44 microns by 4-5 microns. Conidia, dark brown, 35-66 microns by 16-20 microns, with three to six transverse and one to two longitudinal septa. Apical cell hyaline to light brown, often producing a short side branch which forms one to several conidia. These side chains are characteristic, occurring frequently. Mature conidia and hyphae prominently echinulate. (Pl. II, fig. 8.)

HISTORICAL ETIOLOGY.

Since "Black Rot" has been known and described, various names have been given to the causal organism. Notwithstanding this, the same fungus probably has been observed when this particular form of the disease has been noted.

Macrosporium tomato Cke. was first¹ reported as occurring upon ripe tomatoes in South Carolina in 1883. Later Galloway² described the disease "Black Rot," giving as the causal organisms *M. tomato* Cke. and *Fusarium solani* Mart. He states that "infection of both green and ripe fruit was readily effected by inserting the *Macrosporium* spores under the skin." *M. solani* was also given by other writers as the causal organism.

Jones & Grout³ in 1896-7 "found that the fungus which causes the black patches on the rotting fruit was an *Alternaria*, and further proved that this fungus did not cause the rot, for green tomatoes inoculated with spores from a pure culture from the tomato remained in a moist chamber until they ripened without showing signs of the rot, and cultures made from tomatoes just beginning to rot would not yield the *Alternaria*."

McAlpine⁴ reported a tomato rot from N. S. Wales caused by *Alternaria rugosa*. The description agrees with that of the one under consideration with the exception of the color of the hyphae, which were neutral to grayish.

Alternaria fasciculata C&E is the name given by Jones & Grout to the fungus which was found growing as a saprophyte upon the tomato. They include as synonyms *Macrosporium*

chartarum Pk., *M. fasciculatum* C&E, *M. tomato* Cke. and *M. maydis* C&E. The description and illustration given agree with that of the fungus under consideration. The two doubtless are identical.

Alternaria fasciculata (C&E) Jones & Grout does not cause a rot of the green fruit but does produce a pronounced decay of the ripe, duplicating in an artificial infection the original black, hard, leathery condition of the tissues.

CULTURAL CHARACTERS.

On 3 per cent glucose agar (+10): At first the mycelial growth is light colored, almost white, fluffy; later it becomes dark gray with medium much darkened. Not an abundant production of conidia.

On tomato agar (3 gr. agar to 100 cc. tomato juice), or stewed tomato or corn-meal: Very similar to the preceding.

On steamed carrot or banana: Growth heavy, fluffy, grayish green. Mycelium blackish green where the surface of glass is touched. Spore production, but not abundant.

On steamed potato: Growth light gray with slight darkening in places. Potato darkened beneath growth. Mycelium not fluffy but clinging mat-like to the surface. No spore production.

RHIZOCTONIA ON THE TOMATO.

HISTORY.

In the Florida station report⁵ for 1905 an account is given of the occurrence of the potato *Rhizoctonia* upon the tomato fruit. "The tomatoes which touch the ground are frequently more or less covered by the fruiting membrane of the fungus, which mars their appearance. So long as the tomato is green and the skin remains uninjured, the fruit remains sound; however, if the skin of a ripe fruit is ruptured in any way, the fungus soon destroys it, producing a brown rot. * * * The size and shape of the spores and the structure of the hyphae agree quite well with

Corticium of the potato." This is the only description found of a *Rhizoctonia* upon the tomato fruit.

SYMPTOMS.

The specimen examined showed no rupture in the external skin visible to the naked eye. The diseased area was plainly distinguishable by the chocolate-colored, slightly wrinkled epidermis. An examination of the underlying tissues revealed the same general color and numerous somewhat darkened filaments penetrating the cells in all directions. No conidia or fruiting bodies of any kind have yet been observed. It has not yet been determined whether this *Rhizoctonia* is *Corticium vagum* B&C, the one that occurs upon the potato.

ISOLATIONS AND INOCULATIONS.

A pure culture of the fungus was obtained by the planted plate method. Green tomatoes only were used in the first series of inoculations. Three days after infection the discolored areas around the points of inoculation measured one-half inch in diameter. In three more days the older external hyphae had formed a close matted mycelial growth, while the new filaments had reached almost around the entire fruit surface. In ten days to two weeks the tomatoes were completely rotted.

In the second series green and ripe fruits were used. Seven days from the time of infection, the green specimens were rotted thruout. The tissues remained firm but were changed to a chocolate brown and emitted a toadstool-like odor, which is characteristic of new growths of the fungus. The ripe tomatoes presented much the same appearance with the exception of a greater softening of the tissues and a heavier external mycelial growth. This growth is very peculiar and characteristic in its radiately-arranged filaments spreading in a clinging, mat-like manner. (Pl. VIII, fig. 22.)

The fungus spreads thru the green fruit readily as the ripe after it has once gained an entrance. Its power to enter the

fruit thru the unbroken epidermis has not as yet been demonstrated.

VEGETATIVE CHARACTERS OF THE FUNGUS.

The fungus agrees with the descriptions of *Rhizoctonia* in general,^{6, 7} especially in the following details:

"The young branches are inclined to the direction of the growth of the parent stem, and the former are somewhat narrowed or constricted where united with the latter.

"Young hyphae are strongly vacuolate but later they become uniformly granular and more deeply colored. Branching also seems to have occurred more nearly at right angles to the main hyphae." (Pl. IV, fig. 11.)

The numerous sclerotia produced (Pl. III, fig. 10) are made up of closely septate hyphae. The cells which compose the hyphae may be very irregular in shape and dark colored or the cells may be of a lighter brown and vary little in form, making up almost straight hyphae (Pl. IV, fig. 12). Such aggregates of hyphae are very easily broken up, each cell having the power of forming a new growth.

CULTURAL CHARACTERS.

Tomato agar: At first, white, matted growth clinging to medium; later the growth darkens next to the medium and a few sclerotia are formed.

Stewed tomato: Similar to preceding.

Corn-meal: In two days mycelial growth thinly spreading over corn-meal cake, with a fluffy white ring at its edge. Later, dark brown sclerotia with a dented central portion are formed. (Pl. III, fig. 10.)

Compost: A slight growth which soon disappeared.

Steamed potato: In twenty-four hours fungus colony 15 millimeters in diameter, thin mycelium, potato cylinder browned over a great portion of its exposed surface. Later typical sclerotia are formed.

Glucose agar: At first mycelium thin, spreading, white, later-producing sclerotia similar to preceding.

Steamed carrot: Mycelium identical with that upon potato. The manner of growth is more *Rhizoctonia*-like, the filaments spreading parallel to each other, while along their lengths numerous sclerotia are formed.

"RIPE ROT" OR ANTHRACNOSE OF THE TOMATO.

Colletotrichum lycopersici Chester.

SYMPTOMS.

The diseased spots may vary from small, sunken, smooth areas, sometimes darker in color than the surrounding healthy tissue, again yellow and dotted with the small fruit masses or acervuli of the fungus, to large roughened areas, brown to almost black, covering an entire side of the fruit. A great many of the older spots have a characteristic which is very noticeable, that is, the zonation rings. These are plainly shown in Plate I, figure 1. In such a concentrically arranged spot the acervuli will be massed together in circles, while a portion of firmer tissue with no external evidence of disease intervenes. This zonation may be noticed in the first photograph taken of this anthracnose by Chester.^s In Plate I, figure 3, the diseased area either presents a homogeneous surface with the acervuli arranged promiscuously, or only a slight zonation is noted. In the several isolations and inoculations made, it was observed that the tomatoes kept in the light developed this zonation while the cultures in the dark formed an even, continuous growth. No field observations were made, however, as to the position of the various fruits with reference to sunlight and shade, altho this is probably the cause of the appearance or nonappearance of the fruiting rings.

The deeper tissues of the anthracnose spots are always filled with an immense number of spores. These commence to be formed as soon as the fungus has grown for a day or two. The acervuli are only found after the growth has continued for some time.

HISTORICAL ETIOLOGY.

Gloeosporium phomoides was first described by Saccardo²⁰ as producing a rot of ripe tomatoes.

In 1884 Arthur²¹ reported the same fungus as "rupturing the epidermis and producing great numbers of spores on the ends of the protruding mycelium."

In 1891 Chester⁸ found that a fungus which caused an anthracnose of the tomato was a *Colletotrichum*, and believing it to be a new species named it *C. lycopersici*. In 1892 he says⁹ "the fungus which in 1891 was clearly a *Colletotrichum* from the abundant development of setae was in 1892 without setae and to all appearances a *Gloeosporium*." In 1893¹⁰ "inoculation of tomatoes with what was apparently *G. Phomoides* resulted in at first a pinkish stroma without setae but which afterwards turned darker and developed perfect setae. In artificial cultures of the fungus it seems to bear a relation to age."

Cobb¹¹ in 1895 reported a "pimply rot of the tomato." While he did not name the causal organism, the photograph and description of the disease agree with that of *C. lycopersici* Ches. The spore measurements are much smaller, 2-3 microns by 5-7 microns.

In 1898 Miss Stoneman²² gives a brief description of both anthracnoses. She states that "the colonies of the two anthracnoses are quite different. The *Gloeosporium* acervuli lie well imbedded beneath the epidermis, the short continuous basidia not projecting beyond the host. In the *Colletotrichum* colonies the acervuli are erumpent and the setae are sometimes lacking; black spherical perithecial-like bodies are formed which produce long setae. These so far as has yet been determined are sterile. The conidia formed freely on the mycelium do not mass up in large heaps."

Gloeosporium phomoides Sacc. is reported as causing the ripe rot of the tomato by Halsted^{12, 13} in 1895 and 1896, while in 1905¹⁴ he names the fungus *Colletotrichum phomoides* Sacc. Rolfs¹⁵ in 1905 gives the name of the anthracnose as *C. lycopersici* Ches.

Confusion seems to have existed as to the proper naming of the anthracnoses. However, conclusions drawn from these previous investigations point to the occurrence of two anthracnoses upon the tomato, one produced by *Gloeosporium Phomoides* Sacc. and one by *Colletotrichum lycopersici* Ches. The former is characterized by an imbedded acervulus without setae, while the latter forms an erumpent acervulus with or without setae.

FUNGUS CHARACTERS.

The conidia measure 10-18 microns long by 2.5-5.5 microns wide, which is somewhat less than that given in the original description.⁸ The size of setae and acervuli agree. In a 3 per cent glucose agar (+10) culture at 26° C., the fungus spores germinate in a few hours. In 18 to 24 hours an abundance of primary conidia are produced. They are formed by the pinching off of the hyphal end of the simple conidiophores, which process requires only one-half to three-fourths of an hour (Pl. IV, fig. 13). The spores do not remain in clusters around the hyphal end but soon disappear into the surrounding medium. Their formation was successfully determined by the usual hanging drop method. This manner of spore production is evidently followed by the fungus in producing the quantities of conidia found in the deeper tissues of the anthracnose spot (Pl. V, fig. 15).

Upon artificial culture media, young colonies are white to pink in color. When examined microscopically an abundance of hyphae and conidia are found. Later the colony commences to turn dark at and around the central or older portion. The cells enlarge to two or three times their usual diameter, become more or less spherical in shape (Pl. IV, fig. 14), form many vacuoles, and take on a dark brown color. If an examination is now made, few if any conidia are found in this darkened portion, altho they occur abundantly near the edge of the colony where the new growth continues. As these darkened masses are developed, the conidia formation ceases. The spores which have been produced germinate and grow into a new mycelium. The

latter, due to lack of nutrition, does not produce spores a second time. The blackened areas gradually heap up until they are more or less spherical and somewhat confluent. They are sterile and may or may not produce setae.

At times, especially in freshly isolated cultures, small pinkish heaps precede the formation of the black aggregations. These seem to be the typical acervulus with setae and spores.

Under natural conditions, an examination of the tissues of an anthracnose spot which has not yet produced acervuli, shows an abundant production of primary spores which are formed in the same manner as that of the conidia in cultures. As the spot becomes older, pink acervuli may be formed. These invariably consist of parallel arranged fungus tissue whose hyphal ends bear the setae and the secondary spores (Pl. V, fig. 15). The latter are identical in size and appearance with the primary conidia. As these acervuli become older, the central portion of the fungus tissue turns black (Pl. VI, fig. 17). This process gradually continues until the entire acervulus is one blackened heap (Pl. VI, fig. 16). The setae apparently break or fall off, as little or no evidence was found of their previous existence. The conidia also disappear, falling upon the surrounding tissue or scattering elsewhere.

At times these blackened heaps occur upon the anthracnose spot from the time the epidermis is ruptured by the fungus. In such a case few typical acervuli are developed. The spherical dark aggregations are identical with those produced in artificial cultures. They germinate readily, producing a vigorous growth when placed under favorable conditions.

APPRESSORIA.

The appressoria (Pl. VII, fig. 18) as found in this species are oval bodies, smooth in outline or with knob-like projections, dark brown, and contain a few large oil drops. They are invariably the first objects to come into focus when a hanging drop preparation is examined. Certain hyphae seem to grow up towards the cover glass and when it is reached, thru me-

chanical stimulus or otherwise, these attachment organs are formed.

Conidia placed in a hanging drop of water and incubated at 26° C. produced appressoria within two days. No spores were formed until the third day, when a very few were found. The number of appressoria increased slightly up to the fifth day, after which time there was no appreciable change.

Following exactly the same method and conditions, conidia were germinated in a 3 per cent glucose agar (+10) hanging drop culture. Within twenty-four hours an immense number of spores were produced but no appressoria were distinguishable. By the third day, however, appressoria were developed in greater abundance than in the preceding culture. In both cases the appressoria were formed without reference to the surrounding medium.

While more appressoria were formed in the latter culture than in the former, a greater mycelial growth was made, thus giving a chance and need for greater attachment. Since adverse conditions did not seem to cause a greater production of these bodies, it does not appear probable, in this species at least, that the special bodies formed are for the purpose of tiding the fungus over an unfavorable period. Hasselbring¹⁶ found for *Gloeosporium fructigenum* and Halsted¹⁷ for other species, that "a rich nutritive medium produces only a meager supply of special cells while pure water yields few spores and many dark bodies." There is the tendency that Hasselbring mentions, "the hypha which grows in a nutrient medium commences to form an appressorium but before this is formed the hypha grows out again and attempts to repeat the process," in this way forming an irregular chain of swollen hyphal cells. (Pl. VII, fig. 19.)

ISOLATIONS AND INOCULATIONS.

The fungus was repeatedly isolated in pure cultures by the planted plate method. Exactly the same cultures were obtained from small, smooth, sunken spots, as seen in Plate I, figure 2,

as from well developed spots (fig. 3) which had produced an abundance of acervuli. These cultures were used indiscriminately in the inoculations.

Four days after infection the diseased area measured one-fourth inch in diameter on the average. This was true of both green and ripe tomatoes. No acervuli were formed at this time but an internal examination gave evidence of an abundant formation of the primary spores.

The spots increased in extent slowly even under ideal conditions. In two weeks' time, or longer, the size of the diseased area had increased but little; the acervuli had made their appearance, however, as small pinkish heaps. These gradually increased in density and color, eventually becoming black masses of cells, setae and spores.

CULTURAL CHARACTERS.

Tomato agar: Cultures one week old. Growth heavy, compact, membrane-like, pink with an abundant production of spores. Later growth roughened with the black masses of acervuli scattered over the surface.

Stewed tomato: At first mycelial growth clinging to surface of medium, brownish pink. Later, surface blackened with masses of acervuli.

Three per cent glucose agar (+10): The fungus presents the same appearance as upon tomato agar.

Corn-meal: At first mycelium grayish green, not membranous but rising slightly above the medium; colony edge pink, shading into white. Later when mycelial growth is carefully scraped away, the characteristic small heaps or acervuli may be seen next the medium.

Potato: Mycelium pink, edged with white and covering medium closely. Acervuli next medium hidden by the filamentous growth.

Carrot: Growth resembling that upon the potato.

Banana: Mycelium at first fluffy, later, in month-old culture, medium shrunken, black, covered with a roughened heap of acervuli.

FUSARIUM SP.

SYMPTOMS.

The first tomatoes which ripened in one garden under observation were apparently sound and healthy, the external surface was smooth and plump with no evidence of internal softened areas. However, upon cutting into the fruits, a fourth to one-half of the inner tissues was found to be darkened and shriveled. The dry, shrunken, greenish black tissue was usually located near the center of the fruit, in the cavities around the seeds. The external thick tissues were usually healthy and firm, giving the tomato a normal appearance externally (Pl. I, fig. 5). The tissue was repeatedly examined but no evidence of the presence of fungus filaments was found. The examinations were not satisfactory, however, on account of the dry, collapsed condition. Bacteria were frequently observed.

ISOLATIONS AND INOCULATIONS.

Pieces of diseased tissue were at various times placed in glucose agar plate cultures, but no constant results were obtained. The same was true of the various poured plate series.

Several times similar bacterial colonies developed around the points of inoculation in the planted plates and in the series of poured plates, in such abundance that it was thought these might be the causal organisms. Pure cultures were obtained and inoculations made into both green and ripe tomatoes, but no infection resulted.

In one series of poured plates, numerous fungus colonies of similar appearance developed. From a pure culture of this fungus, inoculations were made into the green and ripe fruits. After three or four days, the fungus hyphae had penetrated the surrounding tissues to the extent of one fourth to one half inch. The growth occurred the same upon the green and ripe specimens. The hyphae also grew externally in tufts, which were made up of numerous fascicles, which in turn produced a great abundance of conidia.

Isolations from the artificially rotted fruits yielded the original fungus.

Evidently this fungus could produce a rot of the tissues, but the characters of the disease did not resemble the original in any way. The diseased tissues of the artificial rot were only slightly darkened and rather watery in appearance, strongly contrasting with instead of agreeing with the dry, dark green to black tissue of the original. For this reason the fungus is not given a specific name. Altho the connection between the fungus and the specific disease is not known, it is a genuine fruit rot, and as such is described.

DESCRIPTION OF THE FUNGUS.

The conidia germinate in a few hours at 25° C. in a 3 per cent glucose agar (+10) culture, and in twenty-four hours the short germinating tubes have produced an abundance of spores. Two kinds of conidia are formed, microconidia and macroconidia. The microconidia are borne upon very short conidiophores, being hardly more than a side growth of the cell (Pl. IX, figs. 28-32). The conidia are formed by the simple process of constriction. They remain clustered around the hyphal end until six to eight spores are massed together, when the particular hypha ceases to form more. Conidia are nonseptate, oval, and measure 3-4 microns wide by 4-14 microns long.

The macroconidia are produced in a similar fashion at the ends of long conidiophores (Pl. IX, figs. 23-27), the latter perhaps bearing microconidia upon short side branches. From the number of conidia whose growth was continuously observed, only two became uniseptate and then only just before germination took place. When plain agar was used in the place of glucose agar, the conidia were much smaller and commonly one to two septate, resembling somewhat the typical *Fusarium* spore.

The macroconidia commonly measure 3-5 microns by 16-22 microns.

HISTORICAL.

Beach¹⁸ mentions a blackening of the tomato fruit tissues which may be seen externally as well as internally. The disease "occurred most frequently on the early fruits of rapidly growing plants but continued to appear thruout the season. The remarkable feature of this rot is the total absence of fungus hyphae from the tissues of the fruits in the early stages of the disease." This is the only report found in which reference is made to this peculiar condition of the tomato fruit.

CULTURAL CHARACTERS.

Tomato agar: Growth rather fluffy, white, with a shade of lavender.

Stewed tomato: Growth fluffy, white with a pinkish tinge.

Corn-meal: Growth fluffy, white with a tinge of lavender, medium changed to a purple which is very characteristic.

Glucose agar: At first culture is pure white, later becoming purple at the edge of the medium. The lavender pigment does not extend into the hyphae but remains in the medium.

Potato: Growth clings to surface, rising but slightly above it, pure white.

Carrot, banana: Mycelium compact, fluffy, soon filling tube, white.

FUSARIUM SOLANI MART.

SYMPTOMS.

The outside of the fruit presents an unbroken epidermis. The diseased area is recognized by a wrinkled area, somewhat darker red in color than the surrounding epidermis. The underlying tissues are of a lighter color, shrunken and filled with fungus filaments. The central portion of the diseased area is compact, dry and can be lifted out as a "core." The tissue around this shows dark red, softened areas, which upon examination reveal a great hyphal development.

ISOLATIONS AND INOCULATIONS.

From the pure cultures obtained by the usual method, inoculations were made into the ripe and green tomatoes. In three to five days the rotted area on the ripe fruits measured from one-half to one inch in surface diameter, and extended one-third thru the entire fruit. The hyphae grew externally in tufts, which produced an immense number of sickle-shaped spores.

The fungus seems to have very little effect upon the green fruits, penetrating the tissues but slightly. However, the mycelium is able to grow sufficiently to produce a tuft of external hyphae, which attain a slight growth and then become dormant.

DESCRIPTION OF THE FUNGUS.

The conidia germinate in a few hours at 26° C. on ordinary culture media. In twenty-four hours a dense mycelium is formed but no spores are produced until the fungus has grown for two or three days. The conidia are borne upon upright conidiophores which may be simple or branched. The branching is very characteristic, the conidiophores often presenting a tree-like effect with their side branches, and the not uncommon three terminal branches.

The conidia are sickle-shaped, three to five septate and measure 24-44 microns by 2.5-5 microns. No microconidia have been observed. (Pl. X.)

HISTORICAL ETIOLOGY.

The fungus under consideration doubtless is the same as Galloway² has described. The illustrations of the two fungi point to the same species. Galloway also found that *F. solani* would not penetrate the green fruit altho it so readily produced the decay of the ripe.

This last year a bulletin¹⁹ has been issued which describes a fungus (*Fusarium solani* Mart.) which was able to produce a rot of even the small green fruits, blackening the tissues in a peculiar way. This characteristic and the manner of spore production point to another species rather than to the one under consideration.

CULTURAL CHARACTERS.

The fungus was grown upon tomato agar, stewed tomato, corn-meal, glucose agar, potato, carrot and banana, with similar results. The mycelial growth is fluffy, cottony, varying from pure white to white with a pinkish cast. After a few days an abundant production of conidia upon all media.

PREVALENCE OF THE ROTS.

The Experiment Station plat and two home gardens were under observation.

The anthracnose or "ripe rot" of the tomato was found upon almost all of the later tomatoes which ripened in the plat of the Experiment Station, rendering the fruits practically worthless. This rot did not occur in the two other gardens.

The peculiar blackened condition produced by *Fusarium* sp. was found in fully one half of the earliest fruits which ripened in one of the home gardens, as shown by the numbers of tomatoes which were cut open and found to be in this condition.

The other rots occurred in greater or less abundance during the main part of the season. The loss was not estimated as no check was available as to the amounts of fruit there would be if no disease occurred.

PREVENTIVE MEASURES.

The tomato rots, like the majority of all plant diseases, can not be held in check to any great degree after they are once established. Preventive measures applied in time, however, should keep the loss of fruits at a minimum.

The measures here recommended are gleaned from the reports of different experiment stations where experiments for the prevention of tomato disease have been carried on thru several successive seasons.

The work of Halsted was carried on thru seven successive seasons. Some of the results obtained may be summed up as follows:

Tomatoes may grow and thrive upon the same land year after year, with the employment of proper sanitary measures. As compared, however, with tomatoes grown upon land under rotation, the fruit is inferior in quality and quantity, and is much more liable to rot.

Plants which have an upright position with smooth, thick-skinned fruits, as the "Dwarf Champion," are freer from disease than the trailing thin-skinned varieties, "Stone." The training of the vines was not found advisable.

It is advocated by others²³ that "any system of training which allows free access of air and sun to the fruits and holds plants above the ground, decreases the rot. However, branches must be pinched out, or the trellis becomes an interminable mass of foliage."

Sanitary measures should be employed at all times. The rotting, decayed fruit should be removed and burnt, and a thoro application of Bordeaux mixture should be given every two weeks during the growing season.

The Department of Agriculture²⁴ as far back as 1889 gives this convincing evidence of the benefit of efficient spraying.

Section	Treated with	Loss from rot
1.....	Bordeaux mixture	4 per cent
2.....	No treatment.....	60 per cent
3.....	Ammoniacal solution.....	20 per cent

Bordeaux mixture of the formula 6-4-50 or 5-4-50 should be used.

Acknowledgments are due Dr. F. D. Heald, Botanist of the Station, for his kindly help and advice given at all times, and Mr. W. H. Hein, Field Assistant, for specimens collected.

BIBLIOGRAPHY.

1. Cock: *Grevillia*, 12:32. 1883-84.
2. Galloway: Rep. of Chief of Sec. Veg. Path., 1888:344.
3. Jones & Grout: Bull. of Torr. Bot. Club, 24:257. 1897.
4. McAlpine: Agr. Gaz. of N. S. Wales, 7:304. 1896.
5. Rolfs: Ann. Rep. Florida Exp. Sta., 1905:46.
6. Duggar and Stewart: Bull. Cornell Exp. Sta., 186. 1901.
7. Rolfs: Bull. Colorado Exp. Sta., 91. 1904.
8. Chester: Ann. Rep. Del. Exp. Sta., 4:62. 1891.
9. ———: Ann. Rep. Del. Exp. Sta., 5:80. 1892.
10. ———: Ann. Rep. Del. Exp. Sta., 6:111-115. 1893.
11. Cobb: Agr. Gaz. N. S. Wales, 6:858-9. 1895.
12. Halstead: Ann. Rep. N. J. Exp. Sta., 16:294. 1895.
13. ———: Ann. Rep. N. J. Exp. Sta., 17:335. 1896.
14. ———: Ann. Rep. N. J. Exp. Sta., 24:546-7. 1903.
15. Rolfs: Ann. Rep. Florida Exp. Sta., 1905:45.
16. Hasselbring: Bot. Gaz., 42:135-142. 1906.
17. Halsted: Ann. Rep. N. J. Exp. Sta., 13:303. 1892.
18. Beach: Bull. N. Y. Agr. Exp. Sta., 125:305-6. 1897.
19. Smith: Tech. Bull. Mass. Exp. Sta., 3. 1907.
20. Saccardo: *Michelia*, 2:540. 1882.
21. Arthur: Ann. Rep. N. Y. Exp. Sta., 3:38. 1884.
22. Stoneman: Bot. Gaz., 26:74 and 95. 1898.
23. Bailey and Lodeman: Bull. Cornell Exp. Sta., 32. 1891.
24. Galloway: Ann. Rep. U. S. Dept. Agr., 1889:418.

EXPLANATION OF PLATES.

Plate I.

Fig. 1. Tomato fruit with large mature anthracnose spot showing definite zonation rings.

Fig. 2. Tomato fruit showing the very immature, smooth, anthracnose spots which have produced but slight indentations.

Fig. 3. Two tomato fruits showing large anthracnose spots with a homogeneous arrangement of the acervuli.

Fig. 4. Tomato fruit with portion blackened and collapsed by *Alternaria fasciculata*.

Fig. 5. Tomato fruit showing normal external appearance with collapsed internal darkened tissue caused by *Fusarium* sp.

Plate II.

Fig. 6. *Alternaria fasciculata* showing method of conidia formation.

Fig. 7. Section thru portion of tomato tissue hardened by the *Alternaria* rot and showing the intensely dark cells surrounded by brown colored closely massed ones.

Fig. 8. An adjoining cavity filled with a loose mass of fungus filaments.

Plate III.

Fig. 9. Glucose agar culture of *Alternaria fasciculata* isolated from an artificially infected fruit.

Fig. 10. Sclerotia formation of *Rhizoctonia* upon a corn-meal cake.

Plate IV.

Fig. 11. Immature *Rhizoctonia* hyphae showing the vacuolation and peculiar constriction at the origin of the branches.

Fig. 12. Sclerotia hyphae, with short, brown colored cells.

Fig. 13. Time development of primary conidia of *Colletotrichum lycopersici*.

Fig. 14. An aggregation of enlarged, spherical, vacuolate, dark brown cells, the forerunner of the blackened masses found in artificial cultures and occasional natural infections of *C. lycopersici*.

Plate V.

Fig. 15. A section thru a typical acervulus of *C. lycopersici* showing the fungus hyphae and primary conidia in the underlying tissue and the parallel arranged fungus filaments rupturing the epidermis of the tomato fruit and bearing setae and secondary conidia.

Plate VI.

Fig. 16. Section thru a blackened spherical heap of *C. lycopersici*. The dark fungus cells have completely replaced the tissue of the acervulus.

Fig. 17. Section thru an acervulus which is just commencing to be replaced by the blackened fungus cells.

Plate VII.

Fig. 18. Appressoria of *C. lycopersici* formed in a 3 per cent glucose agar (+10) culture.

Fig. 19. Sometimes before an appressorium was completely formed the hypha grew out and attempted to repeat the process, forming an irregular chain of hyphal cells.

Plate VIII.

Fig. 20. A tomato fruit artificially infected with *Fusarium* sp.

Fig. 21. A tomato fruit artificially infected with *F. solani*.

Fig. 22. A tomato fruit artificially infected with *Rhizoctonia*.

Plate IX.

Figs. 23-27. Time development of macroconidia of *Fusarium* sp.

Figs. 28-32. Time development of microconidia of *Fusarium* sp.

Plate X.

Fig. 33. Conidial formation of *Fusarium solani*.

PLATE I.



PLATE II.

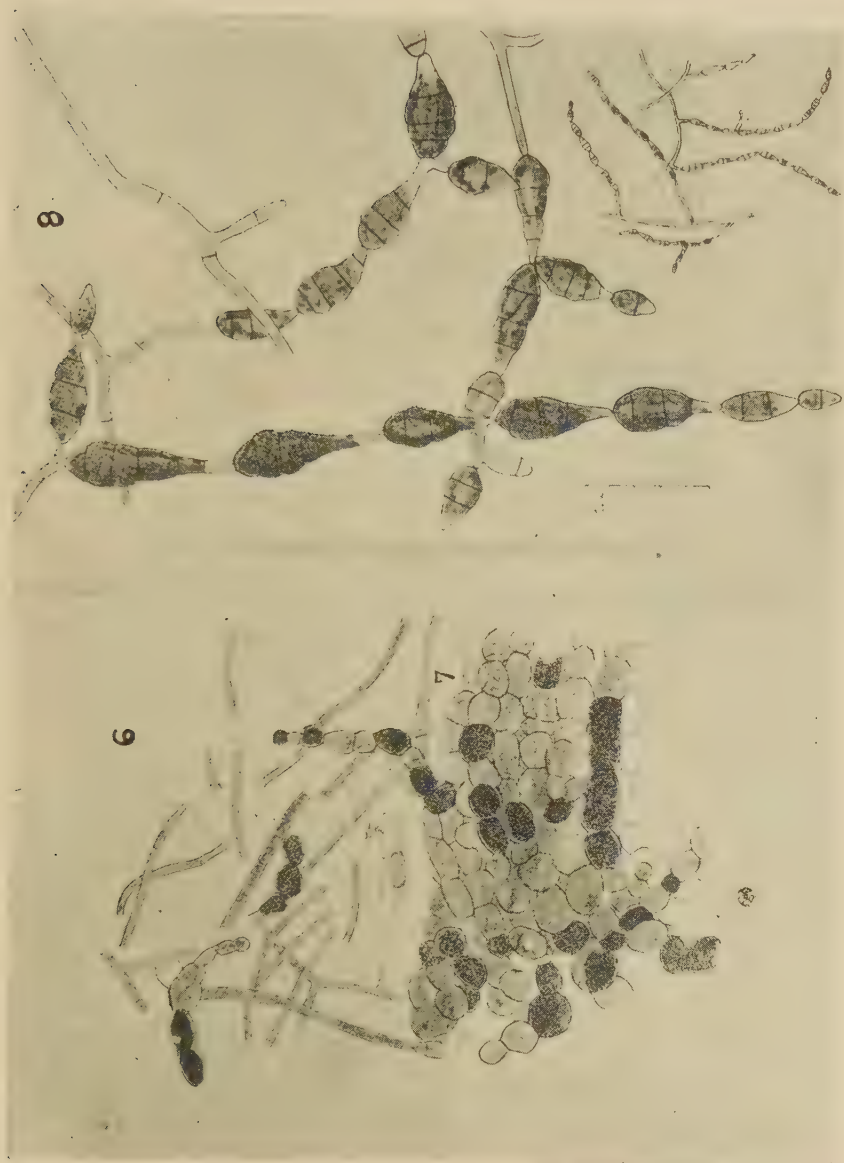


PLATE III.

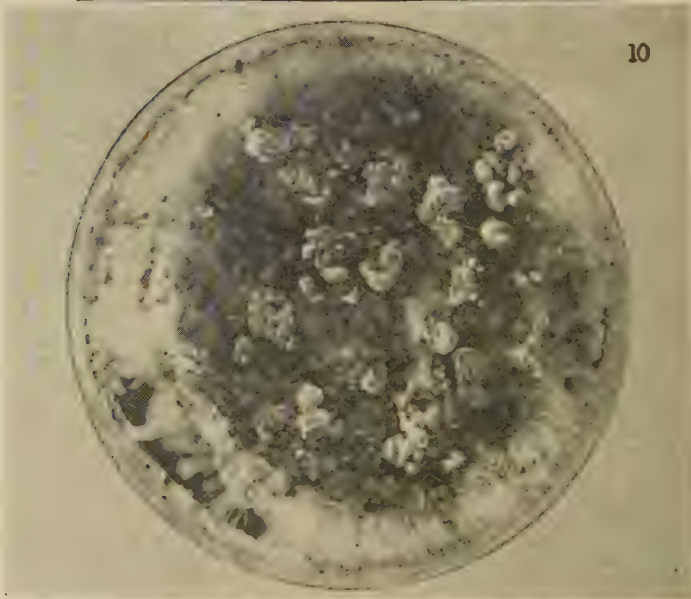


PLATE IV.

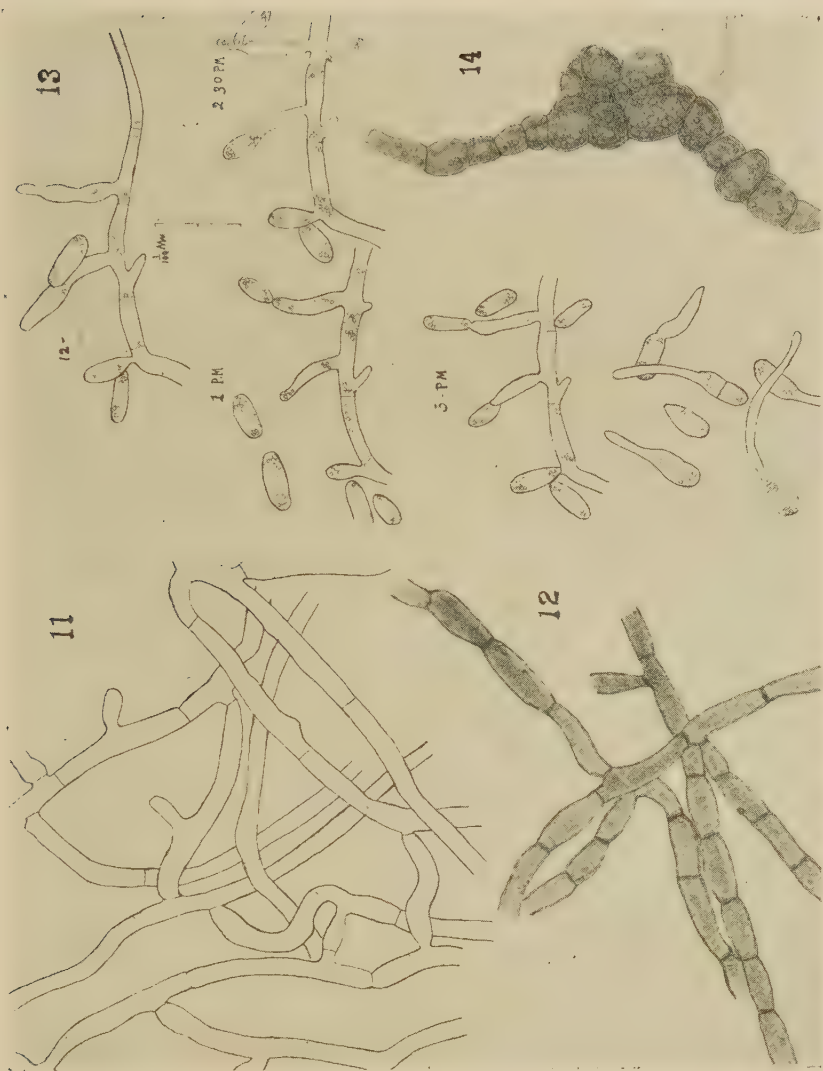


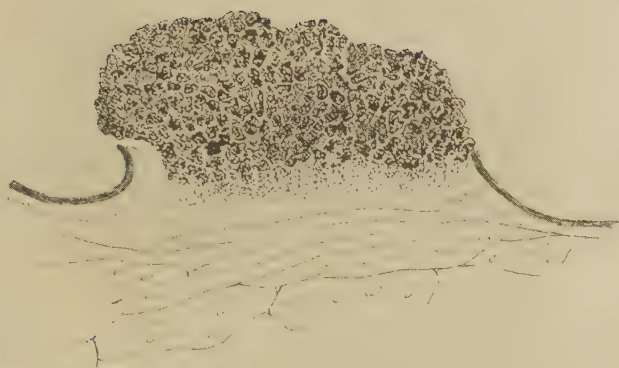
PLATE V.

15



PLATE VI.

16



17



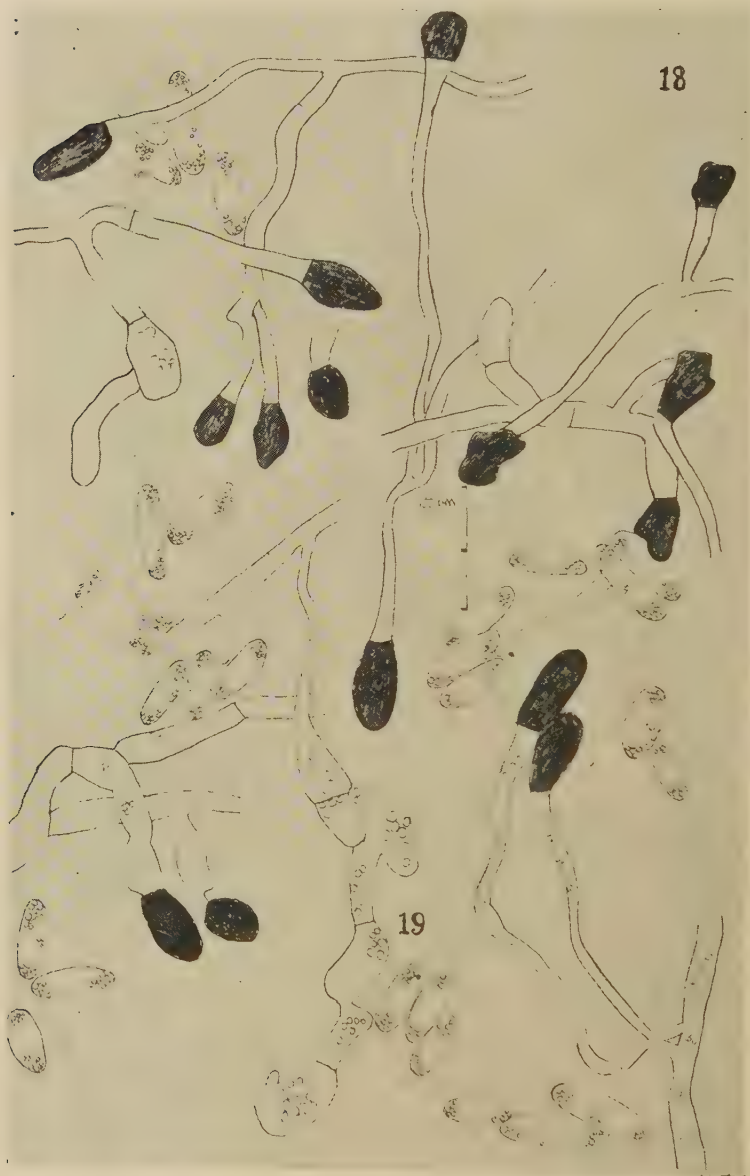


PLATE VIII.



PLATE IX.

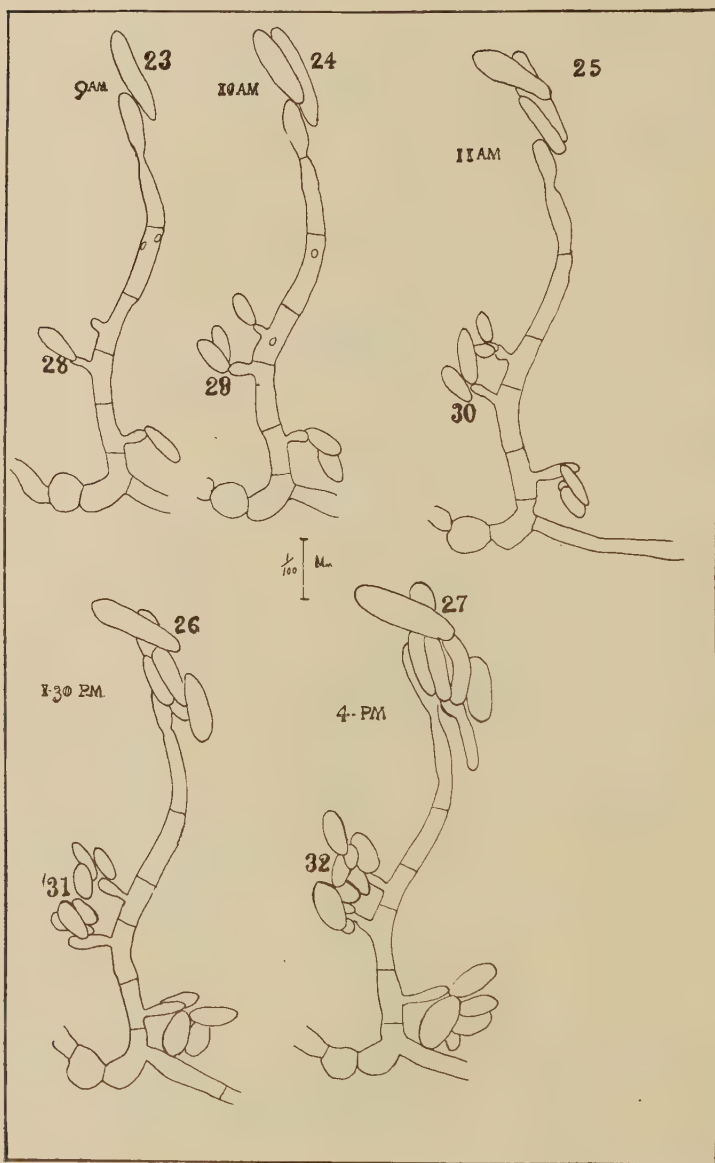
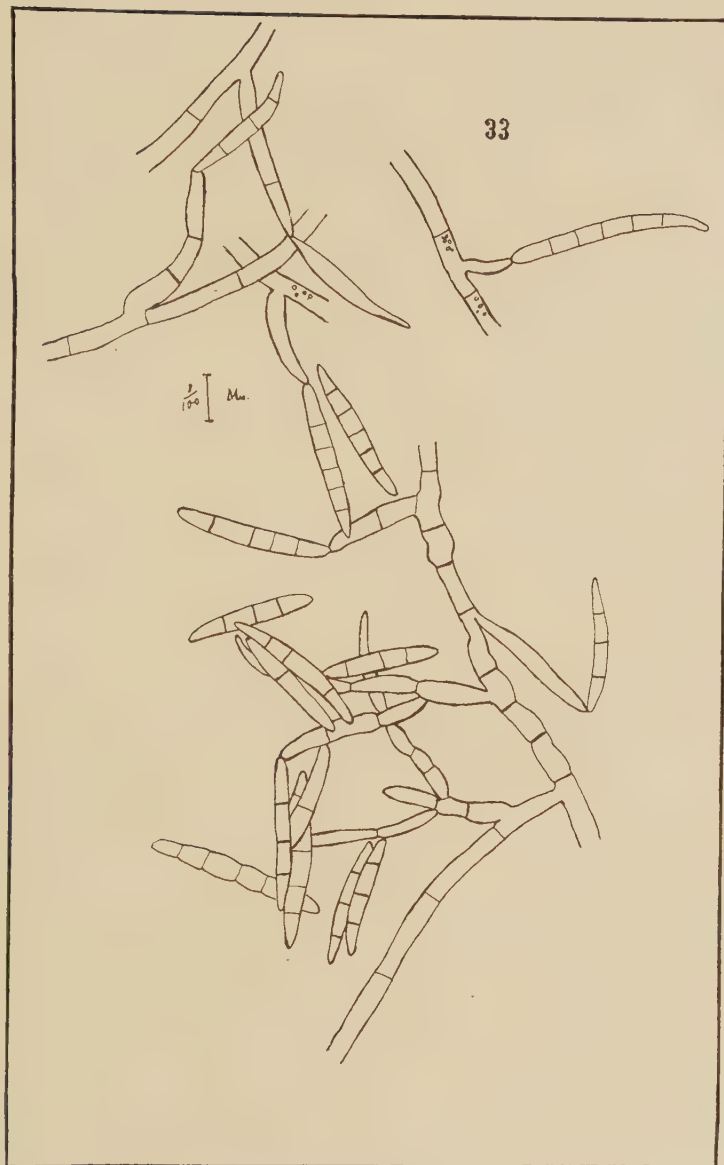


PLATE X.



A NEW FORM OF *SPHAEROPSIS* ON APPLES.

BY LEVA BELLE WALKER.*

Two forms of *Sphaeropsis* have been observed which are capable of producing a severe black rot of the apple. The macroscopic appearance of the rots is very much the same. The principal differences in the two forms are in the size of the spore, the size and thickness of the pycnidium, and the absence of the ostiole in the new form. The new form also seems to be a much more vigorous rot producer.

In this discussion the typical *Sphaeropsis malorum*, the new form and the differences and possible relations of the two forms are respectively considered.

SPHAEROPSIS MALORUM.

Sphaeropsis malorum Peck is the well known fungus that causes the black rot of apples. It has been very fully described and it is only necessary to refer to the publications of others.

Peck¹ described the fungus and gave diagrammatic illustrations of the spores, pycnidia and appearance of the apple.

Considerable work has been done to show the identity of the fungus with *Macrophoma malorum*² and *Sphaeropsis rhoina*.³

Paddock⁴ proved the identity of the fungus causing the black rot and the canker of apples and also made a large number of cross inoculations with *Sphaeropsis malorum* and other *Sphaeropses* which show that the size of the spores varies with the host and not with the species. He gives no work on the pycnidial form.

Delacroix⁵ gives a review of previous work and some original

*Assistant in the Department of Botany, University of Nebraska.

work on the pycnidial form. He shows illustrations of cankered limbs, sections of pycnidia from cankered limbs, spores, etc., but his illustrations are quite diagrammatic.

Kinney⁶ gives a good description of the fungus and illustra-



1



2

FIG. 1.—Section of *Sphaeropsis malorum* pycnidium taken from a green apple mummy, illustrating typical pycnidia with oval spores.

FIG. 2.—Spores from the same apple.

tions of spores and of rotting apples; and most of the Experiment Station publications mention the disease, giving cuts of rotted apples, cankered limbs, etc., for the macroscopic recognition of the disease. Where the minute structure is spoken of at

all, mention is made of the oval or egg-shaped spores and the broad ostiole of the pycnidia.

Longyear⁷ gives a detailed drawing of a pycnidium and spores and a brief, very careful description of the fungus and of the diseases caused by it.

One form of the *Sphaeropsis* under consideration agrees perfectly with this description.

Stevens⁸ and others mention its attacks upon green fruit. This has been observed very commonly by the writer, as many green apples mummied by the fungus are found during the winter. In sections of such apples the fungus filaments do not seem to penetrate deeply into the tissues of the apple.

All who have given careful study to the fungus found oval or egg-shaped spores 20-25 microns by 10-11 microns and a broadly conical pycnidium with an ostiole corresponding with Saccardo's description. (Figs. 1 and 2.)

THE NEW FORM OF *SPHAEROPSIS*.

The new form of *Sphaeropsis* is much the more common, seemingly. It was first isolated from an apple badly affected with black rot in the fall of 1906, and has since been isolated from other similar apples. In every case the same characteristics have been observed.

CULTURAL CHARACTERISTICS.

The fungus has been grown upon all the common culture media (glucose agar, glycerine agar, plain agar, apple agar, gelatin, Pasteur's solution, corn-meal, potato, etc.). In all cases it has produced the same type of growth, but the growth has been most vigorous upon glucose agar, potato, and corn-meal. The growth is cottony and at first of a slightly grayish-white color. Soon near the surface of the medium the fungus threads begin to turn dark and the culture assumes a dark brown or blackish hue when viewed from the under surface. The color spreads rapidly thru aerial hyphae and all become darker, the extreme surface hyphae alone remaining a light gray color.



FIG. 3.—Enlarged cells found in filaments of the new form as seen in hanging drops.

The fungus hyphae are normally about 3-6 microns in diameter, but often, in examining the apple tissue in which the fungus was growing, very much enlarged cells were observed. Similar cells were obtained in great numbers in hanging drops made of glucose agar, Pasteur's solution, etc. This peculiar formation is shown in figure 3. The walls of these enlarged cells are slightly thicker and the contents very much more granular.

Upon none of the media used have pycnidia ever been found, but sclerotium-like bodies resembling pycnidia were often developed.

INOCULATIONS.

Repeated inoculations were tried in apples, and in every case the black rot was developed. The apples used were first wrapped in absorbent cotton wet with a 1-1000 solution of corrosive sublimate (HgCl_2) for a short time and then placed in a sterile damp chamber. Two apples were placed in the same chamber, one of which was simply punctured, while the other was inoculated with the hyphae of the fungus.

The inoculated apples began to rot around the inoculated spot in a few days and the rot spread very rapidly thru the entire apple. The rotting was much the same as for *Sphaeropsis malorum*, but more rapid. The apples at first turned brown with a blackish discoloration under the skin. Gradually they grew darker and became much wrinkled and shrunken black mummies. Examinations of the decayed tissue and of sections of the rotted parts seem to indicate that the growth of the fungus is largely intercellular.

No definite experiments were carried on to determine the mode of infection of the apples, but it seems evident that the fungus filaments have the power of penetrating the epidermis of the apple, as the check apples would become infected at the point of contact if allowed to touch the inoculated apples after they became badly rotted.

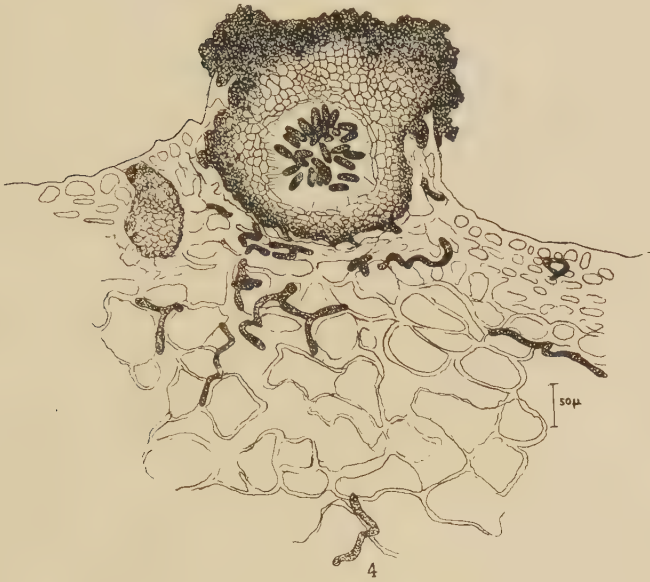


FIG. 4.—Section of the new form of *Sphaeropsis pycnidium*.
FIG. 5.—Same as Fig. 4.

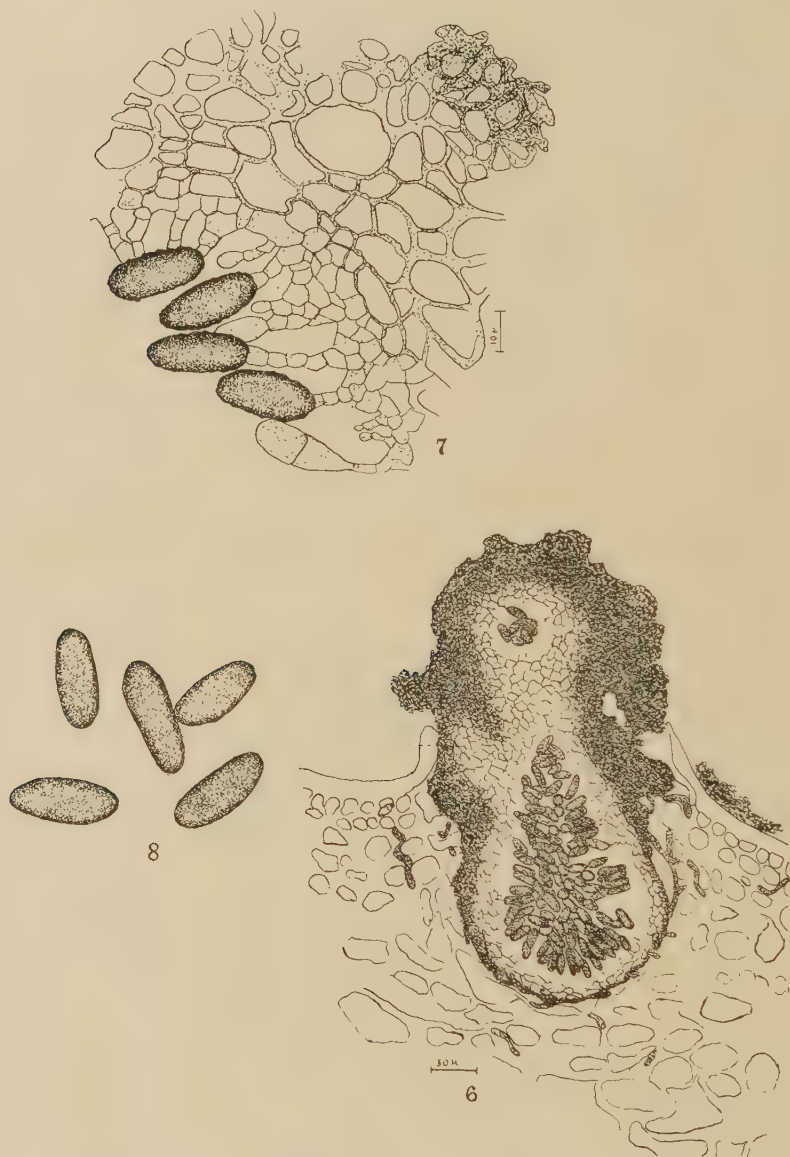


FIG. 6.—Same as Figs. 4 and 5.

FIG. 7.—Detail of the spore-bearing surface of the new form of pycnidium.

FIG. 8.—Spores of the new form of pycnidium.

The pycnidia begin to form very soon after the rot has spread thru the apple and can be easily seen just under the surface of the epidermis. They gradually force their way thru the skin and appear as rough black spots on the apple. Besides these pycnidia many sclerotia-like masses of hyphae form upon the apple. These resemble the pycnidia so closely that the difference can only be detected by the aid of the microscope.

SECTIONS.

Serial sections of several hundred of these pycnidia taken from various inoculations, from different cultures, were ex-

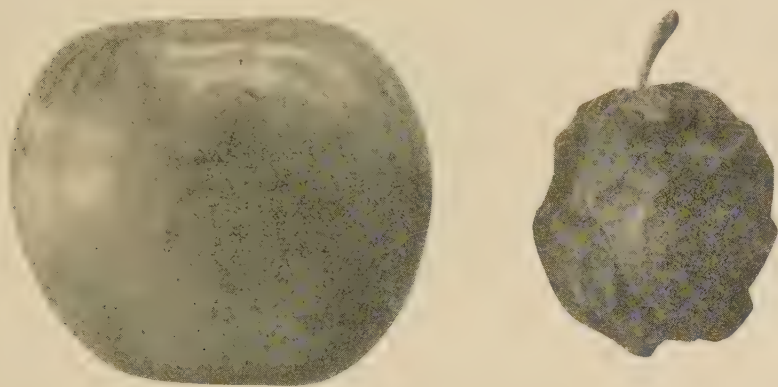


FIG. 9.—Photograph showing *Sphaeropsis* mummy and a check apple.

amined to show the exact formation of the pycnidia, but in no case was an ostiole found. Instead of an ostiole the pycnidium was almost always very much thicker on the outer surface than on the inner. Figures 4, 5 and 6 show typical pycnidia. Dark brown one-celled spores were found in the pycnidia, but the spores were much longer than the spores described for *Sphaeropsis malorum*. The average spores were about 28-30 microns long and 10-12 microns wide, while many spores were as much as 33 microns long. The very smallest spore found was 23 microns long. Figure 7 shows the detail of the spore-bearing surface, and figure 8, mature spores from fresh material.

Thinking that possibly the slightly abnormal conditions in a damp chamber might affect the pycnidial form, sections were made of storage apples and of mummies wintered in the open that were affected with the black rot. The same pycnidial form was observed in all the apples that had pycnidia with long spores, while in those having the typical egg-shaped spores the ostiole was always very conspicuous. In a few cases on half-grown apple mummies the pycnidia containing long spores were but little thicker on the outer surface and it seemed possible that an ostiole might exist, but in examining dozens of sections none were found.

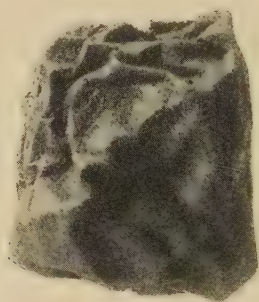


FIG. 10. — *Sphaeropsis* mummy, showing pycnidia.

The size of the pycnidia varied very greatly in the two forms, as is shown by figures 1, 4, 5 and 6, as both forms are drawn under the same magnification.

EXTENT OF INJURY.

So far as it has been observed the long-spored form seems to be a much more vigorous grower and to do much more damage than has been described for *Sphaeropsis malorum*.

In one orchard reported near Blair, Washington County, a large per cent of the apples rotted on the trees from the attack of the fungus.

The fungus penetrates the tissues of the apple so rapidly that the entire apple is rotted before the pycnidia begin to appear, which does not seem to be the case with *Sphaeropsis malorum*.

DISTINCTIONS.

The distinctions between the two fungi can be briefly summed up as follows:

	<i>Sphaeropsis malorum</i> .	New Form.
Size of spore:		
Largest	25 x 12 microns	33 x 10 microns
Smallest	15 x 10 microns	23 x 10 microns
Average	19-20 x 10-12 microns	27-31 x 10-12 microns
Vertical diameter of pycnidia	169-223 microns	300-600 microns
Horizontal diameter of pycnidia	169-225 microns	150-375 microns
Sclerotium-like development	None	Very abundant
Ostiole	Broad, always present	None found
Pycnidial walls	Thin	Thick

SPECIES IDENTITY.

Whether the long-spored form should be considered a new species or a form of *Sphaeropsis malorum* is not determined.

In examining apples rotted by *Sphaeropsis*, none of the typical pycnidia and spores were found till very recently. These were found upon very small green apple mummies. All the other material examined was from ripe or half-grown apples.

Paddock⁴ from his experiments in cross inoculations with *Sphaeropses* concludes that the size of the spore varies with the host.

If the spore size varies with the host, it seems possible that the spore size might vary when grown upon green and mature fruit. And if the spore size varies with the host it would seem quite probable that the pycnidium also might vary. Whether this is true or not can only be determined by further experiments with cultures and inoculations.

LITERATURE CITED.

1. Peck: Ann. Rep. N. Y. State Museum, 34: 36. 1881.
2. Stewart, Rolfs and Hall: Bull. N. Y. Agr. Exp. Sta., 191: 29-331. 1900.
3. O'Gara: Science, N. S., 16: 434-435. 1902.
4. Paddock: Bull. N. Y. Agr. Exp. Sta., 163: 179-206. 1899.
5. Delacroix: Bull. Soc. Mycol. France, 19: 132-141; 350-353. 1903.
6. Kinney: Ann. Rep. Rhode Island Exp. Sta., 7: 192-198. 1894.
7. Longyear: Special Bull. Mich. Agr. Coll. Exp. Sta., 25: 10-13. 1904.
8. Stevens: Bull. N. Car. Exp. Sta., 183: 64-82. 1903.

SEED TREATMENT FOR THE SMUTS OF WINTER BARLEY.

BY F. D. HEALD IN COOPERATION WITH THE DEPARTMENT OF FIELD CROPS.

INTRODUCTION.

Winter barley has been grown on the Experiment Station plats during the past three years and has given a high yield, altho it has been badly infected with smut. The plat grown in 1905 showed 10 per cent of smut as determined by actual count, while in 1906 the count gave 15 per cent. The per cent of smut shown by a count does not indicate the exact per cent of loss by reduction of yield, but is generally somewhat greater than the per cent of loss.

Since seed treatment of barley for smuts has not been as satisfactory as in some other cereals it was deemed advisable to compare some of the different methods and to try a number of modifications. The results of the treatments will be given in the following pages.

DESCRIPTION OF THE BARLEY SMUTS.

Barley is affected by two different species of smuts: the *covered smut* and the *naked smut*. Both of these smuts were present in the field in the season of 1906. The covered smut (*Ustilago hordei* (Pers.) Kell. and Sw.) was present in slightly larger amount than the naked smut (*Ustilago nuda* (Jens.) Kell. and Sw.) The differences in the external appearances of the two species are shown in the accompanying cuts (figs. 2 and 3).

In the covered smut the entire head is destroyed and the smut masses which take the place of the kernels are covered at first with the more or less transparent basal parts of the glumes

(fig. 2). In the younger stages of the disease the awns still persist and they may remain till harvest time, altho in many cases they



FIG. 1.—A bundle of smutted heads for comparison with two normal heads.

are broken off (fig. 2), while the thin membrane enclosing the smut masses may be more or less ruptured, exposing the purple-black spore masses (fig. 2). Under the influence of heavy winds

which prevail under Nebraska conditions, some of the spore-masses that become exposed may be considerably dissipated so that the heads have somewhat the appearance of the heads affected by the other species (fig. 3).



FIG. 2.—Heads of barley affected with the covered smut.

In smutted plants all heads produced from a single stool may or may not be smutted, but in case any heads are free from smut they are frequently reduced in size, and in many cases are less than half the size of normal heads from unsmutted plants. The number of smutted and unsmutted heads in affected stools is



FIG. 3.—Heads of barley affected with the naked smut.

given in the following counts which may be considered fairly typical:

No. of plant.	No. smutted heads.	No. of heads free from smut.
1	10	4
2	3	5
3	7	6
4	9	0
5	3	0
6	9	3
7	4	0
8	6	4
9	4	3
10	6	2

In the naked smut the entire heads are also destroyed but they have an entirely different appearance from heads affected by the covered smut (fig. 3). When the head is just emerging from the leaf-sheath the smut-masses are covered with a thin membrane, but this membrane soon becomes ruptured and the spore-masses are rapidly dissipated. The awns never develop, and with the dissipation of the spore-masses the naked central axis of the head is all that remains at harvest time, and even this is frequently broken off at its junction with the stem. The stems which produce smutted heads are frequently three to six inches taller than the normal ones, and consequently are easily discernible.

THE TREATMENTS CARRIED OUT.

The different kinds of seed treatment used were the following:

(a) *The formalin steep*.—Four different strengths of formalin solution were employed:

Plat 2, 1 pint to 10 gallons water.

Plat 3, 1 pint to 15 gallons water.

Plat 4, 1 pint to 20 gallons water.

Plat 5, 1 pint to 25 gallons water.

The seed to be treated was placed in a coarse sack and submerged in the solution for ten minutes and then removed and allowed to drain to remove the excess of the solution. It was then emptied in a heap and covered with wet sacks for two hours, after which it was spread out to dry.

(b) *The modified formalin steep.*—The seed used for Plat 6 was first soaked in cold water for four hours and then set away in the wet sack for eight hours longer. At the end of this time it was treated with formalin solution, 1 pint to 36 gallons, using the same method as employed for the normal treatment (a).

(c) *The hot-water treatment.*—The seed used for Plat 8 was given the common hot-water treatment. It was soaked 4 hours in cold water and set away in the wet sack for 4 hours more. It was then warmed by submerging in water at 110° to 120° F. for a few minutes, after which it was immersed in hot water, 126° to 130° F. for five minutes and then spread out to dry.

(d) *Corrosive sublimate steep.*—Two different strengths of corrosive sublimate were used:

Plat 9, 3 parts corrosive sublimate to 1000 parts water.

Plat 10, $1\frac{1}{2}$ parts corrosive sublimate to 1000 parts water.

The seed was soaked for fifteen minutes in the solution and then spread out to dry.

(e) *Copper sulphate steep.*—Two different copper treatments were employed, the first of which may be called the *normal* while the second may be called the *modified*.

Plat 11.—The seed was immersed in copper solution (1 pound to 24 gallons of water) for 12 hours, then in lime water (1 pound to 10 gallons) for five minutes, after which it was spread out to dry.

Plat 12.—The seed was soaked in water for six hours, then in copper solution (1 pound to 18 gallons water) for six hours, followed by five minutes in lime water, after which it was dried in the usual manner.

All of the seed treated was dried sufficiently to check germination and prevent heating and was stored in sterile sacks until the time of seeding.

Arrangement of Test Plats.

The treated seed was sown in twentieth-acre plats with the drills running north and south, and three check or control plats

of untreated seed were used, the location of which is shown in the following diagram:

	1	2	3	4	5	6	7	8	9	10	11	12	13	
West	Control	Formalin 1-10	Formalin 1-15	Formalin 1-20	Formalin 1-25	Modified Formalin	Control	Hot Water	Corrosive Sublimate 3-1,000	Corrosive Sublimate 1½-1,000	Copper Sulphate Normal	Copper Sulphate Modified	Control	East

Effect of Treatment Upon Germination and Vigor of Growth.

The per cent of germination was lessened by all of the treatments employed except in the hot water treated seed which showed a perfect germination as contrasted with 97 per cent for the untreated seed used in the check plats. The per cent of ger-

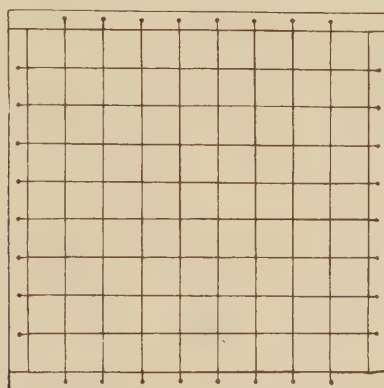


FIG. 4—Quadrat frame, enclosing one square yard, with cross wires at regular intervals.

mination was reduced to 40 per cent by formalin 1-10, and to 70 per cent by 1-15. The vigor of germination was also very much lessened, and the appearance of Plat No. 2 was very poor when examined on October 8, 1906. Not only were the plants smaller

but the stand showed less than half the number of plants in any of the other plats. The amount of seed used on the different plats was made to accord as nearly as practical with the germination per cent, so that the rate of seeding varied from two to four bushels per acre. In order to determine to what extent the rate of seeding employed gave a uniform and equal stand in the different plats, careful counts were made on October 8th. For this purpose a quadrat frame (fig. 4) enclosing one square yard was employed, and the figures given are the result of three counts for each plat. The following table will give the summary of the records for germination, rate of seeding, number of plants per square yard, per cent of smut, and yield:

TABLE I.—*Winter barley experiments.*

Plat No.	TREATMENT.	Germination of seeds.	Rate of seed- ing.	No. of plants per sq. yd. on Oct. 8.	Smut.	Yield.
		Percent.	Bushels.		Percent.	Bushels.
1	Untreated.....	97.0	2	188	30.06	55.60
2	Formalin 1 to 10.....	40.0	4	62	1.57	67.60
3	Formalin 1 to 15.....	70.0	3	151	1.04	77.28
4	Formalin 1 to 20.....	84.8	2 $\frac{1}{2}$	187	1.28	73.20
5	Formalin 1 to 25.....	87.0	2 $\frac{1}{2}$	194	0.50	73.80
6	Formalin (modified).....	93.5	2	142	0.93	70.40
7	Untreated.....	97.0	2	185	24.20	58.74
8	Hot water.....	100.0	2	159	0.72	72.80
9	Corrosive sublimate 3-1000.....	65.2	3	228	1.29	71.20
10	Corrosive sublimate 1 $\frac{1}{2}$ -1000.....	81.3	2 $\frac{1}{2}$	189	2.91	70.80
11	CuSO ₄ (normal).....	86.8	2 $\frac{1}{2}$	202	0.56	70.60
12	CuSO ₄ (modified).....	93.8	2 $\frac{1}{2}$	138	0.73	68.00
13	Untreated.....	97.0	2	172	44.80	58.74

The per cent of smut was determined for each plat by counting the number of smutted and unsmutted heads in three complete drills running the entire length of each plat. The total number of heads counted for each drill varied from 2,220 to 3,375. It was believed that this method would give a much more accurate estimate of the per cent of smut than either the staked quadrat or the quadrat frame method, which are better adapted for use

under general field conditions. The average yield for the control plats was 57.69 bushels, while the yields for treated plats ranged from 67.6 bushels to 77.28 bushels, or an increase in yield per acre of 9.91 bushels in Plat 2, in which the treatment injured the germination per cent and vigor of growth, to 19.59 bushels in Plat 3 which gave the highest yield.

The treatments employed were more effective in preventing the covered smut than the naked smut. The relative efficiency is shown in the following table:

TABLE II.

Plat No.	Total percent of smut.	Per ct. of naked smut.	Per ct. covered smut.
1	30.06		
2	1.57	95.6	4.4
3	1.044	98.0	2.0
4	1.283	90.0	10.0
5	0.506	100.0	0.0
6	0.93	97.2	2.8
7	24.20		
8	0.726	37.0	63.0
9	1.29	68.8	31.2
10	2.91	75.0	25.0
11	0.56	100.0	0.0
12	0.73	100.0	0.0
13	44.80		

It may be noted from this table that both of the copper treatments employed (Plats 11 and 12) were entirely effective in preventing the covered smut, while the naked smut was reduced to slightly more than a half of one per cent. The formalin treatment employed for Plat 5 (1 pint to 25 gallons) was equally effective and entirely prevented the covered smut, while the per cent of naked smut was the least obtained in any of the plats.

RECOMMENDATIONS.

The experiments show that barley smuts can be very greatly lessened by the use of the seed treatments employed. Of these treatments there may be recommended, as about equally effective:

1. Formalin steep, using 1 pint to 20-25 gallons of water.
2. The hot water treatment.
3. The copper sulphate steep.

THE MOLD OF MAPLE SYRUP.

BY F. D. HEALD AND VENUS W. POOL.

INTRODUCTION.

During the past few years a mold has frequently been observed growing upon various brands of maple syrup after they had been exposed in various containers to the air of the household for two weeks or more, and even in the original container if a small amount of the syrup had been removed. The mold generally appeared to be present in pure culture and its abundance and apparent peculiarities of nutrition led to the following study.

HISTORICAL.

Thru the researches of Eschenhagen,¹ Bruhne,² and Thiele,³ it has been demonstrated that some fungi are capable of growing in very concentrated solutions of neutral, toxic, or nutritive substances having a high osmotic equivalent. Thiele in investigating the effect of concentration of medium upon the temperature maximum grew *Penicillium* on solutions containing as high as 70 per cent of grape sugar, and on a medium containing 25 per cent glycerin. *Aspergillus* was grown on medium containing 60 per cent glucose or 25 per cent glycerin. Pfeffer,⁴ in referring to the work of Eschenhagen and Bruhne, states that the optimum per cent of grape sugar for the growth of fungi lies between 5-15 per cent but that some fungi can tolerate as high as 50-60 per cent. *Penicillium glaucum*, *Aspergillus niger* and other fungi are able to grow in solutions so concentrated that their turgor is equivalent to 38 per cent sodium nitrate, or 45 per cent potassium nitrate, which must produce an osmotic pressure in the cells equal to 157 atmospheres. The idea is expressed that fungi will withstand isotonic solutions of different non-toxic substances

making the tolerance to concentrated solutions a matter of turgor adjustment. Raciborski⁵ found that *Aspergillus glaucus* and a species of *Torula* could grow on saturated solutions of sodium nitrate, sodium chloride, or cane sugar, while *Torula* sp. grew slightly on a saturated solution of lithium chloride. Concentration of medium had but little effect upon the color of *Torula*,



FIG. 1.—Natural growth of syrup mold upon maple syrup.

while the cells were reduced in size and shortened. *Aspergillus* failed to show normal color in the more concentrated solutions. That some fungi are able to tolerate a strong solution of a toxic substance is evident from the work of Rostrup.⁶ According to this writer, *Penicillium glaucum* and a *Torula* species were found growing in a solution containing 14 per cent of copper sulphate.

DESCRIPTION OF THE FUNGUS.

The syrup mold upon its natural substratum produces a thin, slightly powdery growth which either spreads quite uniformly



FIG. 2.—Appearance of syrup mold on glucose agar, glycerin agar and plain agar slant cultures.

over the surface or produces distinctly stellate colonies. The young growth is of a pale brown color, turning slightly darker with age (fig. 1). The spores are spherical or sometimes slightly elongated, 2.8 microns in diameter or 2.8 by 4 microns, and are

produced in abundance from elongated club-shaped conidiophores borne in rather dense tufts or acervuli. The spores are borne in chains, but the chains break up, upon mounting, into isolated spores and groups of two, three or four. The root-hyphae extending below the acervuli into the medium are septate and colorless, while the spore-producing branches and spores are of a pale smoky brown.

Our cultures of the syrup mold were examined by Prof. C. H. Peck and pronounced a new species of *Torula* closely related to *Torula sacchari-lactis* Oud.,⁷ from which it differs in the average size and color of the spores and the ultimate branchlets and in the absence of the delicate prickles.

The species may appropriately be named *Torula saccharina*.

GROWTH IN CULTURES.

The syrup mold was easily isolated from its natural growth upon maple syrup since in all of the earlier studies it was the only mold present. For purposes of isolation, 3 per cent glucose agar (+10) was employed and the first sub-cultures made showed that the mold was unable to grow upon plain agar to any extent (fig. 2), indicating that it was not able to use peptone as a source of carbon. In this respect it differs from many other fungi⁸ which grow well with peptone as the only source of carbon, altho both cane sugar and grape sugar present the carbon in a more easily assimilable form. The growth upon some common media is indicated in the following table:

Medium.	Culture.	Temperature.	First appearance of growth	Extent of growth.
Plain agar (+10)	Streak...	10° C.	None.	None.
Plain agar (+10).....	Streak...	18° C.	None.	None.
Plain agar (+10).....	Streak...	28° C.	19 days.	Few small white colonies, slight spore production.
3% Glucose agar (+10)	Streak...	10° C.	5 days.	12 days. Chocolate brown, tumid streak with abundant spore production.
3% Glucose agar (+10) ..	Streak...	18° C.	24 hours.	15 days. Growth covering entire surface, chocolate brown, thick, somewhat folded, medium discolored.
3% Glucose agar (+10) ..	Streak...	28° C.	24 hours. Slight whitish growth.	15 days. Growth covering entire surface, chocolate brown, thick, somewhat folded, medium discolored.
6% Glycerin agar (+10)	Streak...	28° C.	3 days.	19 days. Same as for glucose agar.
Potato (Irish).....	Plate	28° C.	7 days. Distinct, small, brown colonies.	
Potato (sweet).....	Plate	28° C.	48 hours. Distinct brown colonies.	

The preference of the mold for sugar as a source of carbon is shown in the above table, since only a slight growth occurred on plain agar at the end of 19 days, and also since the growth was much slower on glycerin agar than upon glucose agar. The same peculiarity was also shown by the quick germination and abundant growth on sweet potato, and the slow limited growth upon Irish potato.

The growth of the fungus was slightly retarded upon the sugar media by subjecting it to the temperature of the laboratory refrigerator (10° C.). This would indicate that syrup would mold at refrigerator temperature, and the experiments carried out show that such is the case, only a retarding of the molding taking place.

The fungus produces a characteristic growth in plate cultures. The superficial colonies are at first white, distinctly circular in outline, later turning brown with the formation of spores and

becoming decidedly truncate pulvinate. They never increase greatly in size, varying from one-twelfth to one-eighth inch in diameter. The deep colonies remain small and colorless (fig. 3). The character of well-developed colonies is shown in the accompanying figures which represent sections of agar colonies. The center of the colony exhibits a loose network of hyphae, while the periphery shows a region of compact, parallel hyphae which

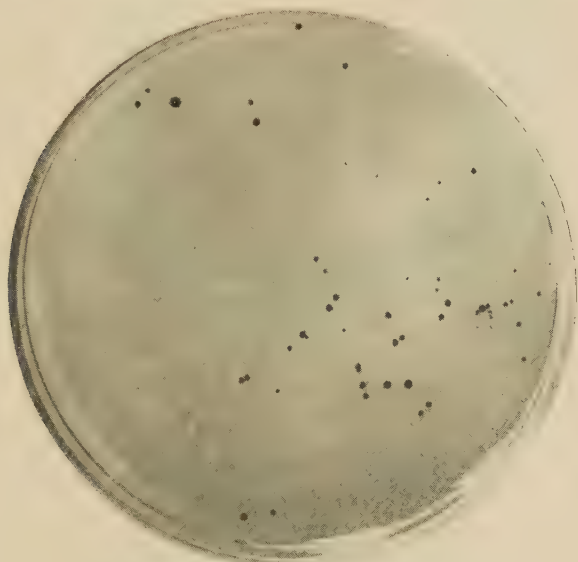


FIG. 3.—Appearance of superficial and deep colonies of the syrup mold. Glucose agar culture.

ultimately ends in the spore-producing branches (figs. 4 and 5). The germination of the spores and the growth of the hyphae was observed in pure hanging-drop cultures. The growth from a single spore is shown in figure 6 from the beginning of germination to the formation of the first spores. A much-branched, sparingly septate mycelium is produced with chains of globular spores.

RELATION OF GROWTH TO CONCENTRATION OF SUGAR.

In order to determine the maximum concentration of sugar which would permit the growth of the mold, a series of cultures



4



5

FIG. 4.—Horizontal section of an agar plate colony.

FIG. 5.—Vertical section of an agar plate colony.

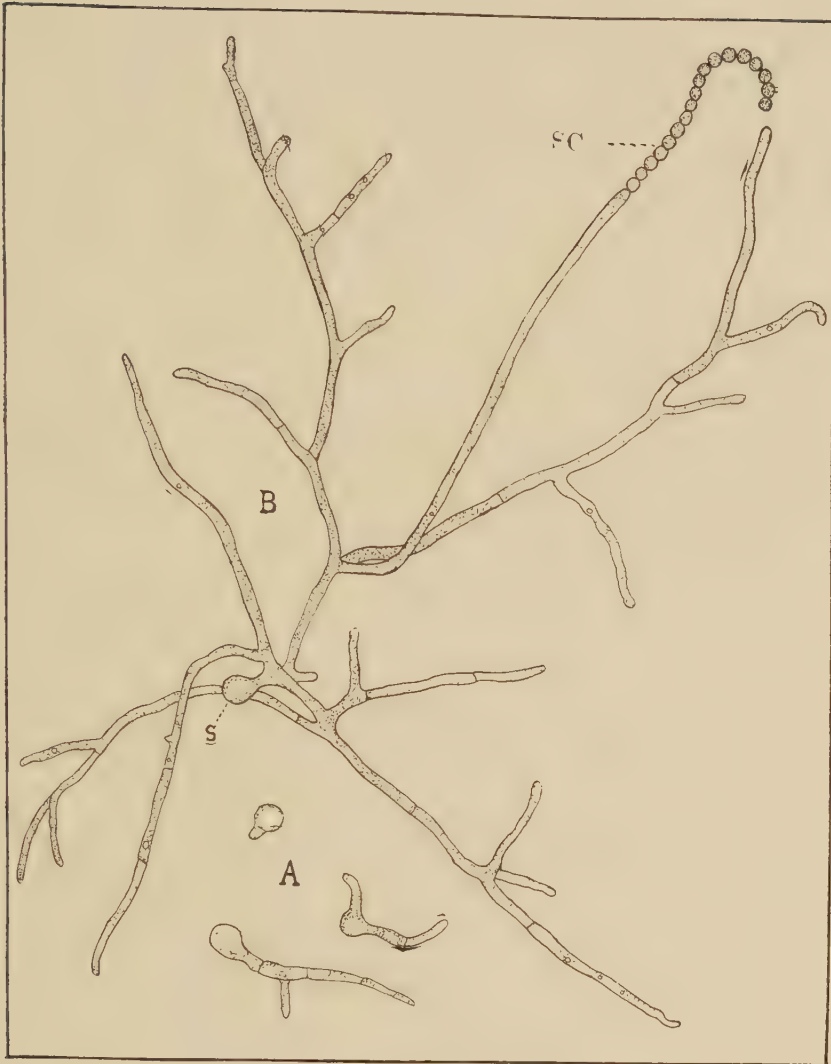


FIG. 6.—Germination of spores and formation of hyphae from hanging-drop cultures. A. Early stages in germination. B. The growth from a single spore. S. The original spore. SC. The first spore chain.

was made using the normal Pasteur's solution, which contains 15 per cent of cane sugar, as a stock solution and increasing the amount of sugar to obtain the different concentrations. The following formula for Pasteur's solution was employed:

Cane sugar	150.0 grams
Ammonium tartrate	10.0 grams
Potassium phosphate	2.0 grams
Calcium phosphate	0.2 grams
Magnesium sulphate	0.2 grams
Water (distilled)	837.6 grams
	1000.0 grams

The cultures were made in 200 cc. Erlenmeyer flasks, and 100 cc. of the medium was employed in each case. The inoculation in each flask was made by adding a small colony from an agar plate culture to each flask, thus insuring a general and uniform infection. The result of the cultures and also a comparison with *Penicillium* is given in the following table:

28° C.		SYRUP MOLD.		<i>Penicillium.</i>	
Medium.	First appearance.	Extent of growth.		First appearance.	Extent of growth.
Pasteur's Solution. (Normal) 15% sugar.	3 days. Colonies at bottom of flask.	8 days. Growth at bottom of flask and a few surface colonies.		24 hours.	6 days. Surface covered with heavy folded greenish growth.
20% sugar.	3 days. See above.	7 days. Surface colonies somewhat larger, fairly numerous.		.....	.....
25% sugar.	3 days. Same as above; slightly more growth.	7 days. Colonies numerous, light brown scum over entire surface.		.....	.....
30% sugar.	2 days. Colonies floating on surface, light brown in color.	7 days. Entire surface covered with worm-like growth.		2 days. Surface $\frac{1}{4}$ covered.	6 days. Large, green, folded mass covers surface.
35% sugar.	2 days. Numerous colonies on surface.	7 days. Surface covered with completely merged colonies.		.....	.....
40% sugar.	2 days.	7 days. Surface covered. Colonies larger.		.....	.....
45% sugar.	.....	.....		2 days. Surface $\frac{1}{4}$ covered with thin growth.	6 days. Surface covered with creamy, somewhat folded mass.
50% sugar.	2 days.	6 days. Entire surface covered; growth piled up.		.....	.....
55% sugar.	2 days.	6 days. Entire surface covered. Colonies separate, slightly spreading.		.....	.....
60% sugar.	2 days. Surface colonies fewer, small, thin.	8 days. Mold covers entire surface; growth thin, brown.		2 days. Slight growth in the solution.	7 days. Growth white, smoothly covering surface.
65% sugar.	2 days. Whitish colonies floating on surface.	9 days. Surface covered with thin, spreading, light brown growth		6 days. Growth slight, thin, white.	12 days. Growth white, slightly folded; microscope showing no spores.
70% sugar.	3 days. One-half surface dotted with small whitish colonies.	9 days. Entire surface covered with spreading light brown growth.		6 days. Growth slight, just visible.	12 days. No practical difference from 6 days.
75% sugar.	3 days. Very few tiny white colonies on surface.	9 days. Entire surface dotted with light brown colonies. Colonies flat, spreading.		.....	12 days. No growth.
80% sugar.	.....	No growth. Colony used for inoculation then placed in gl. agar tube. Good growth in 7 days.		.....	12 days. No growth.
"Canada Syrup."	3 days. Distinct, small white colonies.	15 days. Surface covered with light brown growth. Colonies thin, spreading, no depth.		.....	15 days. No growth.

It may be noted from the above table that the growth of the syrup mold was slower and less pronounced in 15-20 per cent of sugar than in the higher concentrations, while the growth was not completely inhibited until a concentration of 80 per cent was reached. The character of growth upon the concentration of sugar from 60-75 per cent simulates very closely the growth in spontaneous molding and in the pure culture on Canada sap which was carried out for comparison. *Penicillium*, which is a common house mold, did not grow at all in 75 per cent sugar or in any of the maple syrups which were tested.

The inhibition of growth by 80 per cent sugar for the syrup mold and by 75 per cent for *Penicillium* is probably not due to the high osmotic value of the solution. The hydrostatic pressure in the cell-sap of the hyphae growing upon 75 per cent cane sugar must be equivalent to slightly over 50 atmospheres.⁹ It is known that *Penicillium glaucum* and some other fungi⁴ are capable of growing in solutions so concentrated that their turgor is equivalent to 45 per cent potassium nitrate or 157 atmospheres, hence the inhibition of growth by the high per cent of sugar is probably due to low per cent of water available rather than to the high osmotic value.

In a series of cultures in Pasteur's solution in which glucose was substituted for cane sugar, the *Torula* was able to grow in all concentrations from 15-80 per cent. The 80 per cent solution allowed only a few scattered colonies to develop. This shows also that the inhibition of growth is not due to the osmotic effect of the sugar, since glucose has nearly double the osmotic value of cane sugar. In order to grow in 80 per cent glucose, the hyphae would be obliged to develop an internal osmotic pressure equal to 100 atmospheres.

It was impossible to determine the optimum sugar concentration for the growth of the syrup mold by ocular observations alone. An examination of the cultures indicated that the optimum concentration was between 30 and 50 per cent, but no closer estimate could be made. The optimum concentration was

determined from a series of cultures in Erlenmeyer flasks in which the growth was removed at the end of seven days, carefully washed to remove the sugar and then dried to constant weight. The result of the determination is given in the following table:

<i>Medium.</i>		<i>Weight of growth.</i>
Pasteur's Solution	15% sugar.....	0.190 grams
Pasteur's Solution	25% sugar.....	0.218 grams
Pasteur's Solution	35% sugar.....	0.261 grams
Pasteur's Solution	45% sugar.....	0.293 grams <i>Optimum</i>
Pasteur's Solution	55% sugar.....	0.270 grams
Pasteur's Solution	65% sugar.....	0.075 grams
Pasteur's Solution	75% sugar.....	0.116 grams

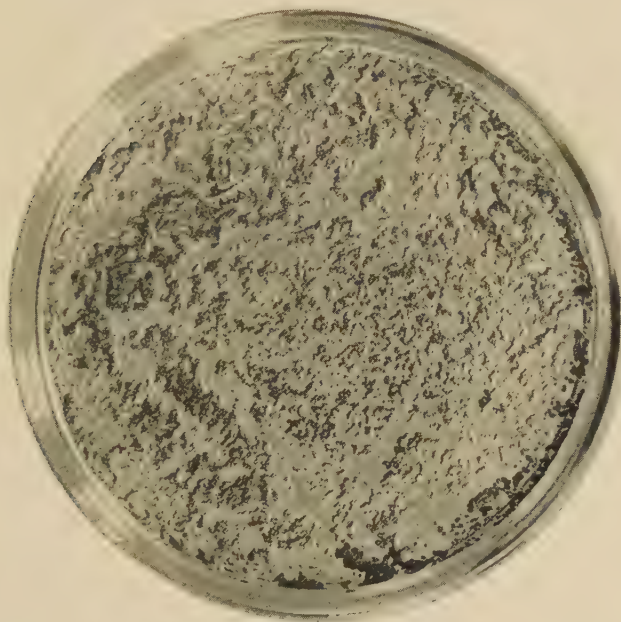


FIG. 7.—Growth of the syrup mold on Pasteur's solution containing 45 per cent cane sugar.

It may be noted from this table that the greatest growth resulted in the 45 per cent solution, while the culture attained a heavier weight in 55 per cent of sugar than in 15, 25, or 35 per cent concentrations.

EFFECT OF CONCENTRATION OF SUGAR ON SPORE SIZE.

The concentration of sugar to which the *Torula* was exposed in cultures in Pasteur's solution had little effect upon the size of either spores or hyphae. The following table gives the average results from a large number of measurements:

<i>Pasteur's Solution.</i>	<i>Spores.</i>	<i>Hyphae.</i>
15% cane sugar.....	3.01 microns	2.58 microns
30% cane sugar.....	2.95 microns	2.58 microns
45% cane sugar.....	3.02 microns	2.58 microns
60% cane sugar.....	3.09 microns	2.58 microns
75% cane sugar.....	3.07 microns	2.58 microns
Canada sap.....	2.75 microns	2.00 microns

EFFECT OF FORM OF NITROGEN ON GROWTH.

A series of cultures was carried out to test the effect of the form of nitrogen on the character of the growth of the syrup mold, and *Penicillium* was used also for comparison. The following substances were substituted in Pasteur's solution for the ammonium tartrate: (KNO_3) potassium nitrate, (NH_4NO_3) ammonium nitrate, and (KCl) potassium chloride. The result is given in the appended table:

28° C.	SYRUP MOLD.		<i>Penicillium.</i>	
Media.	First appearance.	Extent of growth.	First appearance.	Extent of growth.
Variations in Pasteur's solution:				
1. KNO_3 substituted for NH_4 tartrate.	5 days. Surface dotted with small whitish colonies.	8 days. No change.	5 days. White growth—on surface and in medium.	8 days. Surface covered with folded white growth.
2. NH_4NO_3 substituted for NH_4 tartrate.	5 days. Colonies light brown, surface covered, diameter $\frac{1}{2}$ of colonies on 30% Pasteur's solution.	8 days. Color does not become dark brown.	5 days. Growth more nearly resembles NH_4 tartrate solution.	8 days. Growth folded, not so heavy as on 30% Pasteur's solution.
3. KCl	5 days. Surface covered with thin white nontypical growth.	10 days. Growth very thin.	5 days. Thin scum of growth	10 days. No change.

The result shows that ammonium nitrate can be used to a limited extent as a source of nitrogen, but that it is much poorer than ammonium tartrate. The growth in potassium

chloride, which furnishes no nitrogen, was but slightly less than in potassium nitrate.

ANALYSES OF SYRUPS.*

In order to determine whether the molding of the different kinds of syrup was due to the low sugar content, a number of well-known commercial brands were obtained for analysis. These samples, which were in either tin or glass containers and sold for 25 to 45 cents each, have been given a sample number. The manufacturer's name is recorded with the sample number in the records but will not be repeated in this article. The amount of reducing sugars and sucrose in each sample was determined as recorded in the following table:

Sample Number.	Reducing sugars in 100 cc.	Sucrose in 100 cc.	Total sugar.	28° C. Time required for mold to cover surface after inoculation.
1 maple. . .	2.32	57.36	59.68	11 days.
2 maple. ....	.....	.....	.....	12 days.
3 maple.	7.20	59.92	67.12	15 days.
4 maple.	4.04	59.30	63.34	14 days
5 maple.	28.36	38.32	66.68	(few colonies only). 15 days.
6 maple.	21.08	40.27	61.35	12 days.
7 maple. . . .	4.36	52.70	57.06	11 days.
8 maple.	4.74	51.25	55.99	11 days.
9 maple.	13.61	51.45	65.06	13 days.

It may be seen from the above table that none of the syrups analyzed contained a sufficient sugar content to prevent the growth of the *Torula*, but it may be noted that the samples which contained the highest total sugar molded more slowly.

Some experiments were carried out to determine the effect of increasing the sugar content upon the molding. For example, by increasing the total sugar content of sample number 3 to 76 per cent by addition of cane sugar, the growth of the *Torula* was very nearly inhibited, only a very slight growth resulting. The

*Furnished by Dr. F. J. Alway.

per cent of sugar which will prevent or inhibit the growth of the *Torula* lies between 75 and 80 per cent (see table, p. 64) ; hence it is evident that the market articles should be made more concentrated than is the common practice. If the syrups are made sufficiently concentrated little or no growth of mold is likely to occur.

LITERATURE CITED.

1. Eschenhagen: Einfluss d. Losungen versch. Conc. auf Schimmelpilze, 1889 (Leipziger Dissertation).
2. Bruhne: Zopf's Beitragen z. Physiol. u. Morph., 4: 1. 1894.
3. Thiele: Die Temperaturgrenzen der Schimmelpilze, 1896 (Leipziger Dissertation).
4. Pfeffer: Pflanzenphysiologie, 1: 375; 1: 122. 1897.
5. Raciborski: Bull. intern. d. l'Acad. d. Sc. Cracovie, 1905: 461-471. Ref. Bot. Centralbl., 101: 204-206. 1906.
6. Rostrup: Bot. Tidsskr., 26: 89-91. 1905.
7. Saccardo: Sylloge Fungorum, 11: 611. 1895.
8. Nageli: Bot. Mitthlg., 3: 458. 1881.
9. Pfeffer: Pflanzenphysiologie, 1: 128-129. 1897.

A ROT OF GRAPES DUE TO *PESTALOZZIA UVICOLA* SPEGAZ.

BY F. A. WOLF.*

Some ripe grapes that were brought into the laboratory at the Nebraska Experiment Station in September, 1907, were covered with numberless black pustules protruding from the epidermis. A microscopic examination showed that the spores were those which characterize the genus *Pestalozzia*.

Two species of *Pestalozzia* have been described as occurring on the grape in the vineyards of France and Italy.¹ The one, *Pestalozzia thümenii* Spegaz., forms the larger, more numerous heaps. Its pustules are irregular in shape and the cuneiform spores have two hairs, one arising from the vertex and the other from the side. The other, *Pestalozzia uvicola* Spegaz., forms circular pustules and its fusiform spores bear three hairs at the apex. The Nebraska specimens agree in size and character of the spores with *Pestalozzia uvicola* Spegaz. No record has been found of the previous occurrence of this species in America.

Pestalozzia uvicola was first reported in September, 1877, by Spegazzini as being very destructive among the vineyards near Conegliano, Venetia. Von Thümen,¹ who first described this species, gives the characterization as follows: "The spores or conidia are mostly spindle-shaped, five celled; the three middle cells are olive brown, slightly constricted at the points of septation and generally provided with guttae. Both end cells are hyaline, as in other species of *Pestalozzia*, and more or less conical. The length of the spore is 35 microns, the breadth 8-10 microns. At the basal end is a crooked hyaline stalk of uniform

*Field Assistant, Insect Pest and Plant Disease Bureau.

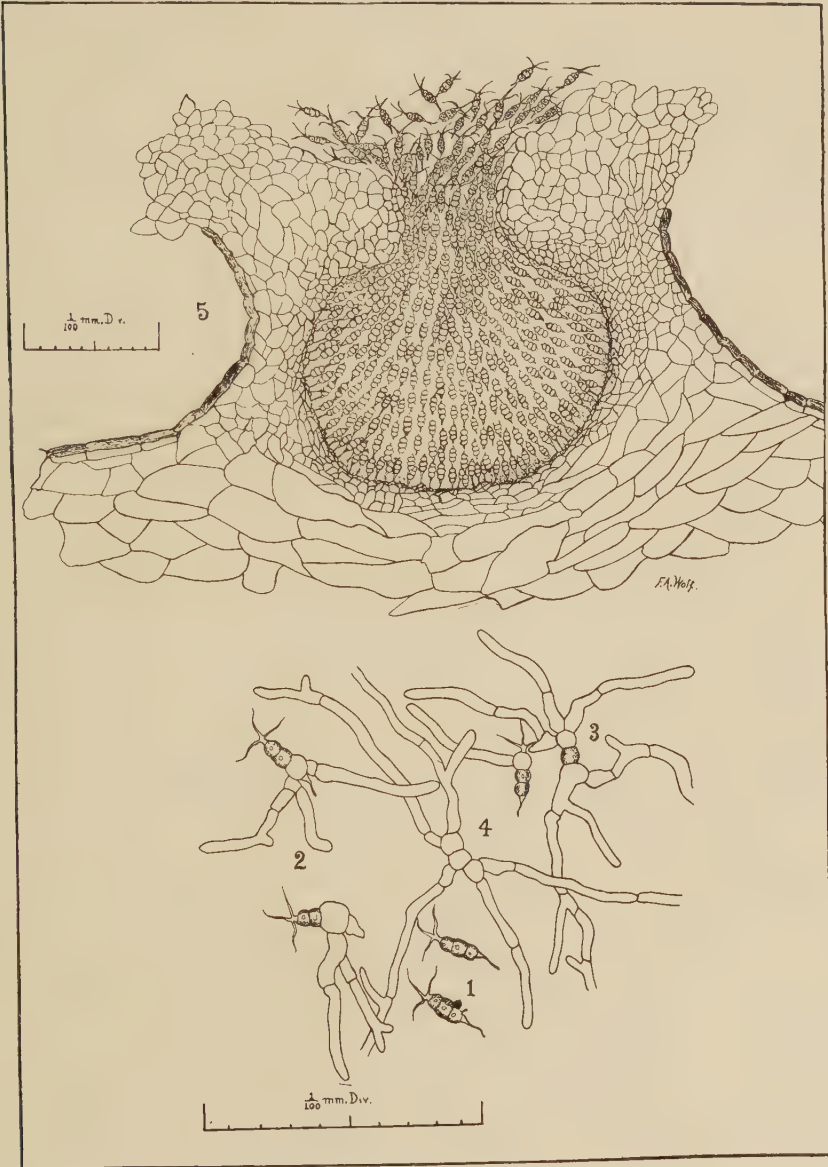
thickness 25-30 microns long and 1 micron broad, while at the upper end are found three characteristic hairs or setae which are colorless, 8-10 microns in length and 1 micron in thickness."

In hanging drop-cultures, in which the medium was glucose agar with a reaction +10, these spores were found to germinate readily and to produce hyphae from all the dark cells, whereas in the species on rotting strawberries the basal cell alone is known to germinate. Not only was a single tube formed, but several from each cell seemed to be more typical and indicative of the intense vigor of the spores.

In order to determine something of the action of the rot, inoculations were made on two separate bunches of grapes in sterile moist-chambers. In one case hyphae from a pure culture of the fungus were used, and in the other spores from the rotted grapes. A sterile needle was used to puncture the grapes and convey the inoculum thru the puncture into the interior of the grape. All the noticeable effect in the succeeding weeks was that circular depressions occurred at the points of inoculation. After a time numerous pustules began to appear on the surface of the inoculated grapes. At the same time masses of spores were developed in the pure culture of the fungus as grown on glucose agar with the reaction +10. The only definiteness about their formation was that it was restricted to one or two places and not promiscuously over the hyphal surface.

Portions of grapes showing spore-producing pustules were imbedded in paraffin. Sections of the pustules did not show a structure as one would expect to find in the *Melanconiaceae*, to which *Pestalozzia* belongs. Massee² says that pycnidia are entirely lacking in this group. Von Tubeuf³ shows *Pestalozzia hartwigii*, a prey of coniferous seedlings, as causing the epidermis to be ruptured, while from the flat surface beneath the ruptured epidermis the conidia are borne. Frank⁴ states that the spores of *Pestalozzia* are liberated thru the ostiole-like break in the epidermis, which is in accord with Von Tubeuf's description. Shear⁵ in his work on the diseases of the cranberry describes and

illustrates a form very similar to those already mentioned. None mention a pycnidial structure for *Pestalozzia*.



In the sections of *Pestalozzia uvicola* the true pycnidial structure was easily demonstrated. The well-defined pycnidium protrudes thru the ruptured epidermis, pushing up the outer epidermal walls and expanding above them into a great mass of pseudo-parenchyma. A relatively narrow ostiole is left thru this pseudo-parenchymatous tissue thru which the spores escape. In some cases the pycnidia were more flat and open than the one in figure 5, yet in all we find that a definite conceptacle is formed by the false tissue within which the spores are formed.

Since it is so evident that this is typically a true pycnidium-forming fungus, we must slightly modify our views concerning its classification. Either it is not one of the *Melanconiaceae* or else the generic description is not adequate unless it is modified so as to include the range of types from the flat surface upon which the spores are formed beneath the epidermis, without any pseudo-parenchyma, to the one which forms a well-defined pycnidium. The latter would seem the less radical measure and could perhaps be easiest accomplished.

LITERATURE CITED.

1. Von Thümen: Pilze des Weinstockes, 15. 1878.
2. Massee: Text-book of Fungi, 395. 1906.
3. Von Tubeuf and Smith: Diseases of Plants, 492. 1897.
4. Frank: Krankheiten der Pflanzen, 2: 440. 1896.
5. Shear: Bull. Bureau of Plant Industry, 110: 6. 1907.

EXPLANATION OF PLATE.

Fig. 1. Spores showing the five cells: the middle three brown, the basal hyaline, and the upper hyaline with three setae.

Fig. 2. Spores which have germinated from basal cell.

Fig. 3. The middle cell alone has not germinated; one cell with three and the other with two hyphae.

Fig. 4. All the dark cells have germinated.

Fig. 5. Showing the pycnidium in section, the great amount of pseudo-parenchyma, the remaining outer wall of epidermis, and the large cells of grape tissue beneath.

A STRENGTH TEST OF HARNESS LEATHER.

BY GEORGE R. CHATBURN.

A farm harness tug, new, with a hame tug, attached by means of the ordinary buckle and a cockeye, was placed in the testing machine and force continuously applied at the end of the hame tug H, and at the cockeye C, until the failure of the tug, which occurred by tearing the leather through the buckle hole at B.



Two tests were made, each of which failed in the same manner. The results were as follows:

First Test:

Failure began by tearing at.....1000 pounds
Maximum loading attained1400 pounds

Second Test:

Failure began at1100 pounds
Maximum loading1570 pounds

Average:

Beginning of failure1050 pounds
Maximum loading1485 pounds

Since the tractive force necessary to haul a loaded wagon on an earth road which is in fairly good condition is about 100 pounds per ton, four tugs of this character would haul a load including the weight of the wagon of

$$\frac{1485 \times 4}{100} = 59.4 \text{ tons.}$$

or with a factor of safety of ten, which is not any too large, the $1\frac{3}{4}$ -inch tug is capable of safely hauling 5.94—that is, practically 6 tons.

On a macadam road this load could be doubled, and on a brick pavement quadrupled.

LOCO WEED POISONING IN HORSES.

BY A. T. PETERS AND L. B. STURDEVANT.

INTRODUCTION.

In July, 1906, the Department of Animal Pathology of the University of Nebraska began an experiment with loco weed poisoning in horses at Imperial, Nebraska. The work was carried on with the cooperation of the Bureau of Plant Industry of the United States Department of Agriculture and with the assistance also of the citizens of Chase county, Nebraska. Dr. C. Dwight Marsh of the Bureau of Plant Industry had already begun his investigations on the loco weed early in 1905, at Hugo, Colorado, and was thus in a position to aid us very materially. His advice from time to time saved us without doubt from many serious mistakes. For the animals used in the experiments and for the use of the fair grounds at Imperial, we are indebted to the Chase county citizens.

The thousands of dollars lost annually by ranchmen in the western part of this state on account of loco weed poisoning in horses, cattle, and sheep was sufficient reason for starting the experiment. The summer of 1906 seemed to be a most opportune time for this research, since the Bureau of Plant Industry had already begun investigations along this line, and we could profit by their past experience.

SYMPTOMS AS HITHERTO DESCRIBED.

The symptoms of loco weed poisoning as described in 1901 by V. K. Chestnut and E. V. Wilcox in Bulletin No. 26 of the Department of Agriculture, Division of Botany, from which we take the liberty of quoting, were as follows:

"Perhaps the most characteristic are those of cerebral origin, consisting in peculiar irregularities in gait and action, which may be compared to a drunken condition in men. Sheep and other animals affected by this disease are commonly said to be crazy or locoed. The cerebral disturbance may consist in an impairment of the function of the special senses, or in improperly regulated motor impulses which produce a more or less pronounced incoördination of muscular movement. Sight is frequently impaired. In some cases the animal soon becomes totally blind. This condition is reached more often in acute cases than in chronic cases of loco disease. More frequently the animal simply sees incorrectly or makes errors in judgment of size or distance of objects. These errors in judgment of ocular perceptions are a common occurrence and are often so pronounced as to become ludicrous. A locoed horse upon being driven up to a gate may either attempt to jump over the crossbar, which is usually placed at the height of about 15 feet, or may lower his head from fear of striking it. Simple experiments indicate that both sheep and horses in a locoed condition frequently mistake harmless things for dangerous enemies. In horses which are affected with the chronic form of loco disease one has abundant opportunity to observe many peculiar and senseless actions which are evidently due to cerebral disease. Locoed horses are often used for both draft and driving purposes. Such horses may work or travel in a perfectly normal manner for days at a time. They frequently, however, run away or are attacked with kicking fits without any apparent external cause. Observations made on horses which are only slightly locoed indicate that they do at times become frightened by purely imaginary objects. This fright would seem, however, to be none the less real, since such horses often tremble or become covered with a cold sweat after these imaginary dangers are passed.

"The sense of hearing is frequently affected in locoed animals, as is easily demonstrated by simple experiments. The response to various sounds and noises is not always in accordance with the

character or volume of the sound. At times a loud noise is unheeded, while at other times a slight noise of the same character may produce fright. The locoed animals are often unable to judge correctly the direction from which sounds come.

"Irregularities of the muscular movements of locoed animals may assume a variety of forms. The animal may simply carry its head in an extended or otherwise unnatural position. In some cases the arched carriage of the back is to be noticed with awkward movements of the legs. Trembling is a frequently noticed characteristic of the locoed animal. This may be confined to the legs, especially to the knees, or may involve all the voluntary muscles, and occurs in a most pronounced manner after any fright which the animal may have experienced. It is often observed of locoed horses that even when they are able to move forward with considerable precision they experience difficulty in backing."

THE PASTURES USED.

The pastures used and the land grazed over were practically all unbroken raw prairie. The most valuable wild grass found here for feed was *Agropyron glaucum*, since it grew in abundance in many places. *Schedonnardus paniculatus* and *Bouteloua oligostachya* were also very plentiful and readily eaten. *Lygodesmia juncea* was eaten about as readily as the grasses and was growing in large numbers everywhere. *Chaetochloa viridis* (green foxtail) was seen occasionally as was also *Cenchrus tubuloides*. One species of *Aristida* was fairly abundant but not eaten after it had developed the "stickers," which the animals wished to avoid. Among the weeds not eaten by the horses the commoner were *Psoralea collina*, *Psoralea argophylla*, *Grindelia squarrosa*, and *Haplopappus spinulosus*, while *Ambrosia artemisiacifolia* and *Polygonum ramosissimum* were not common. *Salsoa tragus* (Russian thistle) was not common but was eaten fairly readily in the green state. *Astragalus mollissimus* (the woolly loco weed) was fairly abundant over most of the unbroken prairie.

FIRST ATTEMPT TO INDUCE LOCO-EATING HABIT.

The experiment was started on July 10, 1906, with three horses from Kilpatrick Brothers' ranch, located nine miles southwest of Imperial. These had been shipped in from Wyoming the previous winter and were rather wild but supposed to be halter-broken. They were in fair flesh. Three other horses were added to those above mentioned and an effort was made to induce these horses to acquire the loco habit by running in a pasture where loco weed was common.

From the first the animals were corralled at night and then, late in the morning, turned into the small pasture, which was hardly larger than a good-sized lot, containing two or three acres. This was with the hope that they would snap at the larger plants including the loco weed in order to quickly satisfy their first and most urgent pangs of hunger. This plan, however, is much more successful in cattle, where the immense size of the rumen demands a space-filling food. It could be noticed, however, that *Lygodesmia juncea* (the rush-like *Lygodesmia*) was eaten considerably oftener in the early morning than later in the day, probably because it is a fairly large weed and fills more space in the same grazing time than any of the grasses.

Of course the personal equation is too large for us to base any radical conclusions on the feeding habits of a half-dozen horses. This much, however, was plain, that when the grass gets very short, hunger will compel many horses to eat this weed. This much confirms the observations of the ranchmen who state that the habit is frequently formed in the early spring or late fall when the grass is short. It is advisable to give a small grain ration to horses turned out to pasture too early or kept in it too late in the fall so that their extreme hunger will not lead them to eat the loco weed. This custom is practiced by a few ranchmen in the western part of the state and with good results. A horse which, by reason of the short grass, nibbles loco weed for a few days, when transferred to good pasture persists in the

loco-eating habit only for the first day or part of it. If compelled to eat loco for a longer time, the habit persists longer and may become permanent as we shall show. A very wet year will frequently produce a large number of locoed animals during the entire summer, probably because the loco plant is unusually succulent then and they get into the loco-eating habit even tho grass is abundant at that time.

On July 28th we abandoned the attempt to induce the loco-eating habit by corralling at night and turning the horses out late the following morning. We began "breaking" the animals into the habit one at a time by shutting them up in the corral and feeding them for a few days with the picked weed.

CASE OF HORSE NO. 1.

Horse No. 1 was a black filly, nearly two years old, which had broken her hip by a fall on the ice the preceding winter. This hip was now healed, so that it did not interfere with her gait. On being turned into the pasture when she was first received, July 10, 1906, she snapped at a loco plant as she walked along, getting a mouthful of the weed, which she ate. She subsequently acquired the loco-eating habit, but only after being "broken" into it, and is not further mentioned in this experiment, since she did not die from the effects of the loco.

CASE OF HORSE NO. 2.

Horse No. 2 was a black gelding, about seventeen months old, with a weak and lax fetlock joint on the left hind leg, which caused him considerable difficulty in using the foot. He ate a piece of dried loco weed in the pasture on July 21st but did not eat loco afterward until specially fed in the corral.

LOCO-EATING HISTORY OF HORSE NO. 2.

Starting with No. 2 on July 28th, he was left in the corral and at 4 P. M. on the day following was fed five pounds of picked loco weed, which he ate readily. On July 30th and the night following he ate 10 pounds of the picked weed, and on the

31st $2\frac{1}{2}$ pounds. He was then turned into the small pasture for the afternoon, when he was offered $2\frac{1}{2}$ pounds of picked weed which was not very fresh and which he did not eat until corralled at 6 P. M. He was left in the corral over night, and the following day ate 6 pounds of the weed in the forenoon and 6 pounds in the afternoon, and was turned into the small pasture at 6 P. M. On August 2d he was corralled all day, eating 6 pounds of loco weed in the forenoon and 5 pounds in the afternoon, leaving about 1 pound uneaten. He was turned into the small pasture at night. On the 3d he was corralled all day and turned into the small pasture at night, eating 9 pounds of picked loco in the forenoon and 4 pounds in the afternoon. On August 4th he was corralled all day and the night following, eating 9 pounds of loco. Four pounds more, which was a little dirty, was offered him at 6 P. M. but was left till the next day, when it was washed to remove the dirt and was eaten during the forenoon. During the afternoon of August 5th he ate 5 pounds of loco and was turned into the small pasture at 5:30 P. M. with access to 5 pounds more loco, which was all eaten by the next morning. On August 6th he ate 13 pounds more of picked loco during the forenoon and on being corralled ate most of $6\frac{1}{2}$ pounds placed there for another animal. He was turned into the small pasture for the night and left there during the day following, when he ate readily 5 pounds of loco in the forenoon and $5\frac{1}{2}$ in the afternoon. On August 8th, while still in the small pasture, he ate 6 pounds of loco in the forenoon and 5 pounds in the evening and the following morning. The total amount of picked loco weed eaten from July 29th to August 8th inclusive was 118 pounds. During all this time the few loco plants growing in the small pasture had remained untouched. On August 9th he was found waiting at the place where he usually received this loco ration and was driven out into the larger pasture. On the way over he ate the first loco plant he came to, walked by the second, ate the third, and then walked

over several more without paying any attention to them. From this time on he was fed with picked loco at intervals more or less irregularly because of the difficulty of getting the weed just when it was wanted. We had no way of measuring very accurately the amount of weed eaten on the prairie or in pasture, but weighed the picked weed as it was fed. We always tried to give all the horses on this experiment grass at frequent intervals, since there is very little nutritive material in the loco and the horses which do not have the loco habit do not eat loco except when forced to by hunger. From August 8th to August 13th, no picked loco was fed. From August 13th to 26th inclusive, 87 pounds of picked loco was fed to this horse. This was an average of about $6\frac{1}{4}$ pounds per day, but varied from 1 to 12 pounds per day. It was impossible to make the daily ration always the same, owing to the difficulty in securing the picked weed just when it was wanted and the further difficulties in keeping it fresh. These were overcome somewhat by dipping the loco in water or sprinkling with water and keeping it piled in the shade and covered with a wet cloth. From August 27th to September 15th he was herded on the prairie most of the time and received no picked loco except 14 pounds on September 6th and 7th. From September 15th to 21st inclusive, he ate 66 pounds of picked loco, an average of $9\frac{1}{2}$ pounds daily. On September 26th he was fed 10 pounds of loco, on the 27th 21 pounds, on the 28th 6 pounds, and was found dead on the morning of September 29th. The total amount of picked loco consumed by this horse was 322 pounds. The first loco fed was eaten 62 days before death occurred.

SYMPTOMS OF HORSE NO. 2.

The symptoms exhibited by Horse No. 2 above mentioned are as follows: On July 10th a diffuse swelling immediately over the masseter muscle was first noticed on the left side of the lower jaw. The animal on this morning tried to get into the corral as tho after loco, eating nearly every loco plant which

came in his road and walking five or six feet out of his way to get some of them. On August 11th, when driven to the water tank, he walked clear around it before drinking. He ate a little picked weed which was being saved for another animal, before being discovered. He ate growing loco plants greedily, passing only a few. The swelling was now (August 11th) on both sides of the lower jaw, extending to the angle of the mouth on either side.

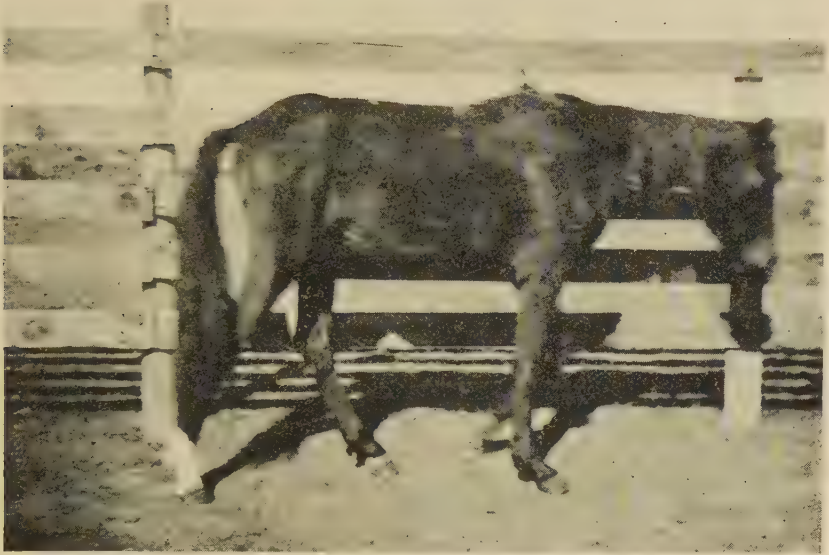


FIG. 1.—Horse No. 2, showing the “hanging” head.

The first place of swelling was not so prominent. On August 12th the swelling had disappeared. On August 14th the animal ate 4 pounds of picked loco readily in addition to that eaten while grazing. On August 15th he was offered picked loco twice but left most of it to go and look for the other horses. On August 16th some enlargement of the lymphatic glands of the lower jaw was first noticed. This enlargement continued till the

time of his death. On this date he circled clear around the water tank and hesitated before drinking. He was still in fair flesh. At this time he began to show a more irritable disposition than formerly, biting at the other horses, especially when No. 3, the sorrel filly, happened to nibble at a pile of picked loco weed where he was eating. Altho he would leave a pile of picked weed occasionally, he always returned to drive off No. 3 when he saw her eating at his pile of loco. On August 19th he allowed one of the larger horses to feed off of the pile of picked loco without resenting it. In the afternoon when the attendant went to drive him to water he had a great fit of fright and trotted away in the opposite direction, snorting twice and at the same time lifting his fore feet very high and showing the characteristic loose-knee action with poor control of the carpal joint.

On August 22 No. 2 drove another horse away from the water pail by first squealing and then biting, and repeated this when the animal tried a second time to drink. A more glassy appearance of the eyes was first noticed on this day. When he arrived at the fair grounds toward evening he walked about as if expecting a ration of picked loco but lay down after being watered and when we left he whinnied after us. This tendency to notice us and show interest whenever we came around increased from this time on and the animal became much tamer than before. He frequently wanted also to stop at the place where he had been fed with picked loco. Stupidity became marked at this time also, the horse standing perfectly still for many minutes at a time. Despite this stupidity the animal exhibited signs of uneasiness, starting to walk many times without any object whatever in view, sometimes stopping soon, at other times continuing to walk aimlessly in a straight line or along the fence. A group of locoed animals will follow each other in a straight line and follow a fence from corner to corner and then down the other side for many minutes or even hours.

On August 23d for the first time he allowed one of the smaller horses to eat at the same loco pile with him. On being caught with a rope he showed great excitement, the muscles of the shoulder and thigh quivered abnormally and he struck out once quickly and wildly with his left fore leg. While trotting he raised both fore and hind legs unusually high, flexion at the



FIG. 2.—Horse No. 2, after being frightened from in front while walking along a fence.

carpus being rather extreme. On August 24th he walked right by a narrowly opened gate, which had to be opened widely to get him thru. He now ate every loco plant which he came across. While drinking in the afternoon he leaned forward against the water tank, with his fore feet, especially the right, very much behind their normal position. On corralling him at night he stayed at the place where he was usually fed with loco weed.

On August 25th he was constantly running away from the pile of loco weed and then back to it again. This nervous or "uneasy" conduct of the animal increased from this time on. The horse would do one thing for awhile and then suddenly leave this and start something else. It was the same way with his grazing, feeding in one place for a short time, then walking to another at a distance of twenty or thirty feet from the first in an aimless way. On being driven to water he was very much excited over some sacks of loco weed that had been left in an unusual place in front of the water tank and rapidly walked back and forth before them. Later he tried to climb over the pipe, which ran from the windmill to the water tank, but gave it up and turned around to walk out from between the two. On August 26th he would eat loco weed from one's hand. He answered the neighing of another horse in a near-by pasture and walked over to where that animal was. He now walked about constantly, never still for more than a couple of minutes at a time. On this day he was frightened twice, once by some boys who were quiet and once by a sunflower moving in the wind. Like a normal horse he frequently failed to show fright where we might reasonably expect it or on the other hand showed it unexpectedly. In general he was frightened more often and more severely than a normal animal. On August 27th he ate mostly loco weed all day, hastening from one plant to another. Once, while grazing, the phalangeal joints of his left fore leg remained flexed for a half minute before he put any weight on them and thus straightened them. The up-and-down motion of his head was now excessive while walking. He came up to the writer once as if for loco weed perhaps, and from this time on he became tamer than ever. On August 29th all the animals drifted on a large patch of wild wheat grass and would not leave it until driven off. On August 30th they left the wheat grass in the afternoon to look for loco weed. On August 31st he would turn his ear to hear us whistle. On September 1st he started for a small dog,

which barked at the horses, as if, perhaps, to strike him, but the dog escaped. On September 3d and thereafter, the horses would go at once to the wheat grass and on being driven off would wander right back. One of them, however, toward the last, would leave the wheat grass to look for loco. All of them carried their heads slightly lower than normal horses and moved much more slowly.

Horse No. 2 was by nature inclined to stumble, but this tendency was apparently much increased by the influence of the loco as was also the case in the others. On September 4th he was found lying down on the prairie in the afternoon, and on being purposely frightened he arose at once, getting up like a cow, on the hind legs first. The hind legs are apparently less affected than the fore legs by the loco weed.

On September 5th the animals were driven under a large white sign with black letters on it. They never seemed to notice it at all altho they were driven under it several times during the summer. Sometimes one of them would shy at the gate which stood at one side but that was all. Horse No. 2 on September 8th left the water tank after drinking but immediately returned and drank again. This was unusual but constituted one of his symptoms of nervousness. By this time there was prominently developed the tendency to follow a road, a ditch, a railroad track, a fence, a buggy, or one of the other horses or even to go ahead in a straight line for many rods on the prairie apparently without reference to any particular end in view. In following a fence he would almost always go right by an open gate. He would persist in following a road or another horse with surprising stubbornness at times, it being a hard matter to make him go in any other direction. At other times, however, he would wander away, usually in search of loco, and remain alone all day, walking very slowly and standing still by turns, but when with the other horses would again show the tendency to follow them. The other animals from now on were less kindly

disposed toward him. Occasionally he would show stubbornness also in wanting to remain out on the prairie when it was time for him to be driven home. His tendency to stumble was more pronounced at this time than ever. He would frequently fall to his knees, regaining his feet in a lively but very awkward manner. In crossing a railroad track or furrow he would raise his feet slowly and very high. This was especially true of his fore feet.

On September 14th he was first observed to void his urine without extruding the penis from the foreskin. Half a minute later the penis was extruded. At this time he walked right by a couple of pails of water and had to be driven back to them, when he drank a considerable quantity. He neighed as the buggy started away leaving him alone on the prairie. The next day he came back to the fair grounds of his own accord. His cheeks at the angle of the mouth appeared to be slightly swollen. From this time on the head was carried somewhat lower than normally.

On the 16th he came in answer when called from a distance of seven or eight rods. On being given a pail of water in the morning he made an awkward lunge forward, striking out with his fore feet but backing off suddenly as if scared. In this case no doubt he suddenly for the moment lost control of his legs. In the later stages of loco poisoning the animals frequently have to catch themselves from falling. Sometimes they do fall indeed and then follows the awkward, hard struggle to again get upon their feet. Most of their motions are "jerky." Even when lifting their hind feet, they bring them up suddenly and rather high, sometimes almost to the belly. As an instance of this inability to control the muscles well, may be cited the almost constant tendency to understep or overstep especially with the fore legs. The former results in stumbling, but the latter does not cause the animal much inconvenience.

On September 17th the horse would not come when called, but neighed, altho not looking in our direction. He would not eat

loco from one's hand on this day but would back away, the quivering of his muscles being at the same time distinctly visible. In getting away while cornered along the fence he acted as tho he would climb the latter. He seemed to be able to back up only with the greatest difficulty. At the loco pile he raised and extended forward his left hind leg several times. This was perhaps another symptom of nervousness. He was taken down by the town to a patch of loco but wandered back in the course of an hour to the road leading by the fair grounds. On the 18th the muscles of the animal's legs quivered violently whenever he was touched or driven. He neighed on seeing us. When confronted along the fence, he reared up and fell over backwards. He apparently could not back up at all. He struggled for a couple of seconds before regaining his feet, the hind legs were up a little before the fore legs. He neighed at and came within twenty or thirty feet of one of the other horses on the 19th of September while out on the prairie. On this day the penis of the animal was extruded before urination. A railroad train passed within thirty yards of him but he didn't seem badly frightened, only trotting away slowly for fifteen or twenty feet. When the attendant stopped driving him for a while he turned clear around and went back in the opposite direction for a minute but soon commenced going one way and then another. The skin of his nose quivered while drinking water. This symptom remained from this time on. The faeces being usually dark and somewhat dry were now still darker than ever. On coming to a deep rut he looked down into it before attempting to cross. His weight was found to be 455 pounds on September 20th. On September 21st, while stepping off the scales down to the ground, a distance of $1\frac{1}{2}$ feet, the horse fell into a near-by mud hole and floundered around for a couple of minutes, only stopping to rest, and finally pushed himself out by means of his hind legs, getting up on his fore legs a second afterward. Later he was startled by the sneezing of a bystander. He

frequently would leave the loco pile, turning to the right and circling around to it again in a small circle of perhaps six or seven feet in diameter. He jerked his head upward once suddenly but without any apparent cause. On seeing some horses by the corner of the lot in which he was confined, he walked over to where they were and stayed for several minutes. He now walked almost constantly and slowly, sometimes, however, standing perfectly still for several minutes at a time. He caught himself from falling once. Several times he lifted his right hind foot slowly for 6 or 7 inches. He did the same thing again later in the day but this time the action was due probably to the irritation of a sunflower which was touching his foot. On September 22d, he could not be induced to drink out of a pail but would walk right over it. He was scared but slightly at an automobile. On this day for the first time we could put our hands on him without his walking away. He was turned loose during that afternoon to shift for himself and look for loco on the prairie, since the Chase county fair had temporarily deprived him of his quarters. He was not found next day after a thorough search. Perhaps he had wandered into some cornfield. He was found late in the afternoon of September 24th, seven miles from home, by the side of the railroad track. After being driven slowly and with difficulty for half of the distance toward home, he balked and started to go around the driver and back in the opposite direction. He was stopped with a whip and he then whirled around slowly to his right about a dozen times in a circle on the same spot and then stood still with both his fore and hind legs widely apart, the right from the left. When it was attempted to turn him about by whipping his nose, he reared up on his hind legs, striking out quickly with his fore feet, and fell, not attempting to rise at once. This last was unusual, as he always, heretofore, had tried to get up immediately upon falling. It was now late in the evening and some water was obtained from a neighboring farm house. Upon

returning with the water the animal was upon its feet. He would not drink out of the water pail when driven up to it but had wanted to stop and drink out of the mud puddles on the road. He walked over one pail and upset it. Another pail of water was slowly placed under his nose and lifted until the water touched his lips, when he drank all right. The penis was



FIG. 3.—Horse No. 2 after being frightened from in front while walking along a fence and near a corner. This shows the poor control over the fore legs.

not extruded to urinate. He was left on the prairie for the night, since he seemed to be completely tired out and it was now dark. He was found in very nearly the same place the next morning, September 25th, when he would not drink when driven up to a water pail even in broad daylight. He nibbled at the handle and at the edge of the pail and apparently sucked at some grass

where the water had spilled. He would not stand still so that the water could be lifted to his lips, so he was driven to a near-by farmhouse where he finally walked up to a tank of water and drank for a long time, after hesitating at every new sight and sound, especially at a mud puddle by the side of this tank. The urine was voided without extruding the penis. On the way home he wanted to stop and eat every loco weed, but a little urging was enough to keep him on a slow walk. He did not turn toward home at the right corner until we compelled him to do so, altho he knew the place well. He would have followed the same road straight ahead if he had been left to himself. On reaching the fair grounds he was placed in the small pasture. That evening at seven o'clock when we called to him he started to walk, but in the wrong direction to find us. In trying to get the animal over to the pile of loco we attempted to turn him by whipping his nose, when he keeled over backwards and fell and did not attempt at once to rise. So the loco weed was placed by his nose and he began eating. He was on his legs, however, in a couple of minutes later.

In the forenoon of September 26th the animal was found to have escaped from the small pasture, and was seen standing still, with head slightly hanging, about two hundred yards south of the pasture fence. He was all scratched up with the barbed wire. He was driven back and shut up in the corral. He had eaten very little loco the night before. On his way back to the corral he took a mouthful of a species of *Aristida* and carried it along in his mouth while scarcely chewing it at all. This grass was full of stickers and was never eaten by the animals. It was of a grayish appearance at this time of year but it is hardly possible that the horse mistook it for loco weed, especially after getting it into his mouth. The horse did not switch his tail much and was fairly covered with flies. Some picked loco was placed in the corral for him. He would take a weed in his mouth, begin chewing it and then walk around the

corral chewing at the same time, forgetting to chew after a minute but continuing to walk. The penis was not extruded to urinate. He walked constantly, the fore and hind legs both being rather widely apart, the right from the left. This latter tendency in horses with loco poisoning is noticed only late in the disease. He would stop at the loco pile only long enough to get a mouthful of the weed. Sometimes he would eat the weed, but more often, after chewing for a time while walking, he would stop chewing and later drop the half-chewed mouthful, apparently by accident, or as tho he had forgotten it, never picking up the weed dropped, continuing to walk all the time and returning to the loco pile a minute later for another weed, only to go thru the same performance. He would turn to one side in order to avoid walking into the attendant.

On the afternoon of the 26th he walked along the fence as usual and would frequently stop, stand still for many minutes at a time and shut his eyes. He would, however, open his eyes and move his ears when we made a little noise. On this day he would not keel over backwards as he had done formerly on being slapped over the head with a cap but would move his head or walk straight ahead, never backing up to get away. He would eat loco from one's hand only when cornered along the fence. An excessive or abnormal secretion was running from the animal's eye over onto his cheek. His hair was rougher than ever. On this particular day, as the horse switched his tail against his body you could hear sparks, apparently electrical, the hair of the tail standing out erratically and part of it clinging to the thigh.

On September 27th he drank water only when it was lifted to his lips. When a pail of water was placed on the ground before him he would walk right over it, sometimes striking it by accident with his feet. His fore feet and hind feet were rather widely separated, the right from the left, both while walking and standing. This shows how much control over the limbs was

lost. He neighed at seeing us, but it was when we were close to him. His stupor was such that many things failed to attract his attention. There seemed to be nothing inherently wrong with his senses. Weeds and dirt in his mane and scratches on his body showed that he had been down.

On the 28th he would eat from our hands. He would not stand still until a pail of water could be brought to his lips, but after we had finally succeeded in doing this, he drank all right. He paid no attention to the sneezing of a man twenty feet away. The animal was now very much emaciated. His hind legs were placed rather far back and widely apart while he was standing still. A little blood was dripping from his nostrils, giving to his breathing a hissing sound. His nose was swollen slightly. His ears had a decided droop laterally. The straddling of his legs was still worse on this day, both while standing and walking.

On the morning of September 29th the animal was found dead in the corral. He was lying on his left side, the legs being at the standing angle with the body. No rigor mortis was present except a very little in one hind leg, altho the horse was cold by this time. The right eye was half open, the left closed. Emaciation was pronounced. His coat of hair was very rough.

POST-MORTEM EXAMINATION OF HORSE NO. 2.

On post-mortem examination of this animal, the organs of circulation were found to be normal. The respiratory organs were also normal, except for a small amount of amber-colored fluid in the nares and some froth in the trachea. The interior of the turbinated bones was greatly congested. The mouth, pharynx and oesophagus of the alimentary canal were normal. The mucous membrane of the fundic portion of the stomach was of a very dark, red color, and almost black in places. The stomach was empty. A few bots were attached to its wall. Bots were also found in the duodenum for the first eight or ten inches, most of these being attached to the wall. The small intestine was

empty thruout, except for a very large amount of yellowish, very tenacious and slightly frothy mucus. Externally on the wall of the great colon, there were several places where the smaller arteries were enlarged. The contents of the great and small colon were apparently normal. In the first half of the great colon, there was found a large number of small nematodes, each about 1cm. long. The liver was normal. The urinary organs were normal. The bladder contained 4 or 5 ounces of urine. All of the organs mentioned so far were slightly lighter in color than is usual in post-mortem examinations. The brain and spinal cord, however, were both congested. A cherry-red, transparent, organized exudate was found in great abundance in the extra-dural space, i. e., between the dura mater and the periosteum of the vertebrae enclosing the neural canal, all along the spinal cord.

CASE OF HORSE NO. 3.

Horse No. 3 was a sorrel yearling filly which had previously broken a shoulder but had sufficiently recovered so that the accident did not interfere with her gait. She nibbled at loco weed on July 21st and 23d, and again during the forenoon of the 24th when in the large pasture, but not in the late afternoon or on the days following.

LOCO-EATING HISTORY OF HORSE NO. 3.

This filly was a few months younger than Horse No. 2 above decribed. She was much slower and lazier but not so much in the habit of lying down in pasture.

On August 13th there had been picked by mistake a few pounds of *Aragallus lamberti* (stemless loco weed or crazy weed, also known as Colorado loco vetch). This weed was first found four miles east of Imperial. It was deemed advisable to feed this to one of the animals and Horse No. 3 was selected, altho for no special reason. On being corralled at 6 o'clock in the evening she refused to eat any of the *Aragallus lamberti* and did not eat it during the night which followed. On the next day, how-

ever, on being left in the corral, she ate 6 pounds of it before 6 o'clock in the evening and was allowed to run at large after that hour. During the next few days she did not nibble loco (*Astragalus mollissimus*). On the morning of August 16th she was driven over to where another animal was eating picked loco. The latter, it was thought, would eat more of it if one of the other horses was there for company. Horse No. 3 started to nibble at the pile of loco but was driven away a couple of times by the biting of the other animal. The same thing also happened in the evening and again on the following day. On August 19th we received some more picked stemless loco weed (*Aragallus lamberti*). Horse No. 3 was accordingly placed in the corral at 3 o'clock in the afternoon and left there. The next day she was fed with this weed and ate, but not readily, $4\frac{1}{2}$ pounds of it, leaving many of the stems untouched. The stems of the weed at that season of the year were particularly tough and dry. On August 21st, before 6 o'clock in the afternoon (after which time she was taken out of the corral and placed in the small pasture), she had eaten fairly readily $3\frac{3}{4}$ pounds of *Aragallus lamberti* upon being driven back to the pile of weed several times. She returned to the weed pile once after seeing one of the other horses eating picked loco. This much might possibly be due to imitation. On August 22d she was kept in the corral from 12 M. until 7 P. M. and during this time she ate readily 4 pounds of *Aragallus lamberti*. On the 23d she started to eat picked loco at the same pile with horse No. 2, this animal permitting it for the first time, and was corralled at 11 A. M. She was left in the corral for the rest of the day and the night following and ate readily during this time 9 pounds more of *Aragallus lamberti*, eating a plant from the hand of the attendant, whom she followed about for a while as tho wishing to be let out of the corral, certainly not wanting either water or weed since she had both. We were now out of *Aragallus lamberti* and picked no more of it afterward since it could not be easily

obtained. On August 25 we offered her, at 6 P. M., 5 pounds of picked *Astragalus mollissimus* (woolly loco weed), which she ate readily. On the morning of August 26 she ate $3\frac{1}{2}$ pounds readily. In the evening she was offered 4 pounds but 2 pounds were found uneaten on the following day. She would now eat loco from our hands for the first time. On the 27th this horse ate readily of picked loco, getting about 1 pound of it. She now also ate growing woolly loco. This was the last picked weed she received except 1 pound on September 6.

The 6 pounds of *Aragallus lamberti* eaten on August 14th was not enough to induce the loco-eating habit. From August 20th to 23d inclusive she was fed 21 pounds of stemless loco above mentioned. On August 25th she ate 5 pounds, on the 26th $5\frac{1}{2}$ pounds, on the 27th 1 pound of *Astragalus mollissimus* (woolly loco weed), receiving 1 pound also on September 6th. Beginning August 20th, this animal received $33\frac{1}{2}$ pounds of picked weed up to the time of her death, September 8th, 19 days later. This is a very short and rapid course for loco poisoning to take and can be explained only on the ground that she ate a large amount of loco in the pasture and possibly to the further fact of her age, her small size, and possibly to her lazy and indolent disposition.

She first showed marked stupidity on August 27th. She would mope along at quite a distance behind the other horses while on the prairie. She would eat scarcely anything but would stand still for many minutes at a time with eyes half closed and with head hanging slightly. At such times she could be aroused by offering her some loco, which she would eat from one's hand. Then of her own accord she would begin grazing on loco and grass, but in a half-minute or so would relapse again into her sleepy attitude. Her other symptoms agreed in general with those exhibited by the horse just described above, so that it will not be necessary to give them in detail. She always, however, showed more laziness and stupidity.

Only a few striking examples of her conduct will be noted. On August 29 the herd boy found her lying on the ground but part way up with her fore legs under her body. He could not get her up even by whipping and by pulling upward on the tail. At 10 A. M. she was up and grazing with the skin mostly gone from the front side of both forefeet at the level of the fetlocks. On September 4, on walking into a few loose wires, she did not look at them closely but walked ahead, lifting her feet very high and showing poor control over them. On September 5th, while getting her onto a platform which was six inches above the ground, it was necessary to lift her fore feet, one at a time, and place them on the raised place, after which she walked onto it all right. On September 7th she was standing at 8 A. M., but down at noon. A man who happened to be present tried to make her get up by whipping her on the withers but failed to do so.

POST-MORTEM EXAMINATION OF HORSE NO. 3.

In only a few particulars did the post-mortem findings of this animal differ from those of Horse No. 2. The superior wall of the abdominal cavity showed much congestion beneath the peritoneum. The stomach did not show any congestion but the mucous membrane lining the cardiac portion of the stomach could be easily stripped off. The stomach and intestines contained a good deal of millet, which, however, the animal had been used to eating occasionally. Four specimens of *Ascaris* were found in the jejunum as well as two tapeworms in the ileum. There was a slight excess of mucus present in the first five of six inches of the jejunum. Externally on the wider, longitudinal, ligamentous band of the caecum were two spots each an inch or more in diameter, where the blood vessels were enlarged and engorged. The spleen was bluish-black in its middle third, its caudal end was bright red, while the other end was dark blue. The spleen weighed about half a pound. The other organs were like those of Horse No. 2.

CASE OF HORSE NO. 4.

On July 13th, Horse No. 4, a pot-bellied black yearling gelding belonging to Mr. Frank McClain, was added to the experiment. This animal was rather wild and had a noticeable tendency to stumble over rough places in the road. He was a little older and larger than either of the animals just described. His tendency to stumble greatly increased as the experiment proceeded.

LOCO-EATING HISTORY OF HORSE NO. 4.

At 6 P. M. on August 25th he was corralled and offered 4 pounds of picked *Astragalus mollissimus* (woolly loco weed), this species being adhered to in breaking in this animal. He began eating fairly well and the weed was all eaten on the following morning when he ate 4 pounds more. In the afternoon of August 26th at 5:30 he was fed $1\frac{1}{2}$ pounds of loco, which he ate readily. On August 27th all the animals were herded on pasture, and No. 4 ate a good deal of loco in the forenoon but very little in the afternoon. Four pounds of picked loco was eaten by four of the horses in this experiment while in the corral on this day. The loco eating habit had now been formed by No. 4, which received practically no more picked loco weed until October 3d except 14 pounds on September 6th and 7th. On October 3d we began feeding large amounts, since it seemed evident that another month of grazing without additional feeding of loco would not kill the animal. From October 3d to 14th inclusive, on which latter date he died, he ate 196 pounds of picked loco, varying from 1 pound to 45 pounds per day, receiving an average of nearly 18 pounds per day during this time.

SYMPTOMS OF HORSE NO. 4.

On September 23d, on escaping from pasture at the fair grounds, he started on a swift walk down the usual road toward the prairie where the loco grew, but stopped and came back on hearing the neighing of one of the other horses, which he answered. From this time on until the time of his death, on

October 14, he showed practically all of the symptoms of Horse No. 2, with some more pronounced symptoms which will be specially mentioned.

He balked occasionally and could then not be started by whipping. He stayed very close to another one of the horses, especially on one occasion after having been corralled by himself all day, when he pressed so closely against the side of this other animal as if afraid of losing her, that she laid back her ears at him. He lifted his feet higher than any of the other horses in crossing the rails of the railroad track. He stumbled more frequently, and fell as a result of this oftener, than any of the other horses. In the forenoon of October 4th he started down the road along the railroad track and was hard to turn back until he stumbled and fell at the edge of a ditch, when he made one trial to get up, then did not try again for a couple of minutes. After this rest he succeeded all right. On getting up he started straight toward home. On running into some wires which lay on the ground he balked, but after some urging he went ahead slowly, lifting his feet 12 inches or more in order to step over them but not looking down at them at all. When he came to where the fence had been previously, nothing being now left but the posts, he cautiously pressed forward after turning to one side for an instant as tho fearing that the fence wires were still there. On getting out into the open he fairly ran down to the large pasture where Horse No. 1 was, since he had been alone in the corral all day. When the two met they both neighed loudly and long. He pressed close to the side of this animal as tho afraid of losing her. When she would turn in his direction and push against him by accident, his ears would fly back for an instant.

POST-MORTEM EXAMINATION OF HORSE NO. 4.

The post-mortem examination of Horse No. 4 revealed conditions practically identical with those of horse No. 2. The transparent jelly-like and organized exudate in the extra-dural

space along the spinal cord was of a buff color in the sacral, lumbar and last half of the dorsal region, becoming cherry-red in the first half of the dorsal and even brighter, almost a dark red, in the cervical region. The dura mater in the cervical region was distended by a serous fluid. The stomach was enormously distended by loco weed, the organ with its contents weighing about 28½ pounds. The mucous membrane of the cardiac portion was easily stripped off, while that in the fundic portion was intensely congested, amounting to an inflammation. The pyloric portion contained an excessive amount of mucus. This excess mucus continued through the duodenum, jejunum and the first part of the ileum, the last portion of this last organ containing much loco weed, which was not found in any amount in the rest of the small intestines. In the first part of the ileum there were present 31 cestodes (dead when found). These were unusually long specimens, one of them measuring 30 cm. Three specimens of *Ascaris* (dead when found) were present near the junction of the jejunum with the ileum.

Externally and irregularly over the small intestines and great colon some of the smaller arteries were somewhat enlarged and congested in irregular patches, each from two to four square inches in area.

The great colon contained practically no nematodes and was full of loco weed, appearing like normal colon contents. The small colon was full of loco weed, with a very slight excess of mucus. The trachea contained no froth. The pericardial fluid was slightly increased in amount and had a slight reddish tinge. The other organs than those mentioned were all normal or slightly pale in appearance.

CASE OF HORSE NO. 5.

Horse No. 5, a two-year-old bay gelding belonging to Mr. O. P. Shallenberger, was also added to the experiment at this time, but was returned to the owner on request September 16th without having developed the loco-eating habit, and will not again be mentioned in this article.

CASE OF HORSE NO. 6.

Horse No. 6, an iron-gray yearling gelding belonging to Mr. Below, was added to the experiment on July 16th. This animal was crippled with a broken humerus on the left side which had united badly and caused severe lameness. On the right side of his neck, below the mane, was a small tumor, not covered by the skin. A second tumor was present between the forehead and the nose, just below the level of the eye. This animal nibbled at loco weed on July 23d only, when the grass in the small pasture was practically gone. He was allowed to run at large after this date, since his crippled condition made it appear inadvisable to take him over to the large pasture and back again every day. On August 6th we put him in the corral and offered him some picked loco weed, which he refused to eat. We left him in the corral that night. During the next day and night following he ate fairly readily $13\frac{1}{2}$ pounds of picked loco weed. On August 8th and the night following he ate $8\frac{1}{2}$ pounds, leaving about 1 pound uneaten. On the 9th he was in the corral part of the day and the rest of the time in the small pasture, now containing little or no grass. On August 10th he was turned out and allowed to run at large, when he ate readily $4\frac{1}{2}$ pounds of picked loco weed placed in front of him. The next day he refused to eat picked loco placed before him, so he was again put in the small pasture, where he began eating it at once, only one pound out of the eight given him being left on the morning following. On August 12th he finished 8 pounds in the corral and was then turned out to run at large in the evening. On the day following while at large he ate 4 pounds of picked loco readily. On August 14th he was missed in the afternoon and found in the evening of the next day as he was coming out of a near-by cornfield. He was offered loco, which he would not eat, and was then put into the corral for the night, where he ate readily $1\frac{1}{2}$ pounds of the weed. On the 16th he ate about one pound of loco weed but showed symptoms of colic, lying on his side all day.

The noise caused by the churning about of the intestinal contents was distinctly heard. But little gas was present, not enough to produce noticeable distension of the abdomen. The corral gate was opened toward evening, when he was given water from a pail, but he did not, perhaps could not, walk out altho the gate remained open all night. On the day following he drank some water in the morning but could not in the evening, dying some time that night.

Autopsy of this animal on August 18th revealed mostly grass in the first half and apparently corn leaves in the last half of the great colon, while an excess of mucus was found along the small colon. Death was due, in all probability, to colic induced by an unusually large amount of corn leaves, to which the animal was unaccustomed.

SUMMARY.

LOCO-EATING HISTORY.

Hunger will lead many horses to eat loco weed when the grass is short, especially in the early spring or in the late fall, or even in wet seasons when the grass is not short, probably because the weed is then more succulent. A small grain ration when the grass is short will usually be sufficient to keep the animals from forming the loco-eating habit. After a horse has eaten loco for a time, this habit becomes permanent in most cases.

It was permanently formed in Horse No. 2 after 118 pounds of picked woolly loco weed (*Astragalus mollissimus*) had been eaten and probably long before this time. This animal lived 62 days after the picked loco was first fed and consumed a total of 322 pounds of this besides that eaten in pasture and on the prairie.

Six pounds of picked *Aragallus lamberti* (stemless loco weed or crazy weed, also known as Colorado loco vetch) on August 14th was not sufficient to induce the loco habit in Horse No. 3. We began to feed her with this weed again on the 20th. The

loco-eating habit was this time permanently induced in the sorrel colt after $21\frac{1}{2}$ pounds of picked *Aragallus lamberti* and $10\frac{1}{2}$ pounds of picked woolly loco weed (*Astragalus mollissimus*) had been eaten. The animal died 19 days after the first of this weed had been fed, if we except the 6 pounds of *Aragallus lamberti* on August 14th. After the loco-eating habit had been induced in this animal, one pound only of picked woolly loco weed was fed, practically all being eaten while grazing on the prairie.

The loco-eating habit was permanently induced in Horse No. 4 by 5 pounds of *Astragalus mollissimus* fed on each of two successive days. The total amount of picked woolly loco eaten by this animal was $221\frac{1}{2}$ pounds. The horse died 50 days after the first of this was fed.

SYMPTOMS.

The first indication pointing to loco weed poisoning is usually the loss of flesh. The animal becomes very poor. The characteristic "stiff knee" gait also soon becomes noticeable in the fore-legs. The symptom of most value, however, in diagnosing this condition is the loco-eating habit. The horse will eat the weed at almost every opportunity. Distinct irregular swellings more or less bilaterally symmetrical appear early, on the cheeks and side of the lower jaw as well as on the place behind the lower lip. These swellings persist for a day or two and often recur for several times at irregular intervals but with less severity. Distinct enlargement of the lymphatic glands in the intermaxillary space of the lower jaw just in front of the throat is early to be seen. This condition persists. The quivering of the muscles, especially of the limbs, together with inaccurate and jerky movements of these, are best noticed when the horse is excited. They can be brought out very clearly by frightening, handling, or teasing the animal.

The usual habits of a normal horse are preserved to a remarkable degree in this condition. Their memory for places and

things is probably unimpaired. They will usually return after a day or two when they have wandered several miles from home.

They show very plainly their love of company and their intense dislike of being alone. They exhibit signs of fright where we would hardly expect them and on the other hand they fail to show these in many cases where they could be reasonably



FIG. 4.—A locoed horse on being frightened while in a corner and trying to get away. This shows poor control over the fore legs and inability to "back up."

looked for. In general they are more often and more severely frightened than would be the case in a normal animal. We cannot agree with the opinion formerly held by some that a locoed animal becomes frightened at imaginary objects analogously with "ghosts" or "snakes" in the human subject. A locoed horse becomes very tame as the condition progresses. Periods of

stupor lasting for many minutes or even hours, when the animal stands perfectly still with eyes half closed and head hanging, are interrupted temporarily by aimless walking about or by other nervous, "uneasy" actions. The irritable disposition is best displayed when the animal is with other horses. The stubbornness is most in evidence when he is led or driven to some place where he does not want to go. A locoed horse is proverbially slow, or, as it is sometimes interpreted, "lazy." Even then he will frequently run into things before noticing them, but will soon right himself when he is thus aroused from his dreamy stupor. When feeding in a certain spot he will frequently leave it, turning to the right and describing a small circle to return again to the same place. He seems to mistake all small gray objects for loco weeds until a closer inspection shows him his mistake. In his dream-like stupidity also he forgets to fight the flies. He will blindly and even stubbornly follow a fence, a road, or another horse, or go ahead in a straight line for a long distance without any apparent end in view.

A group of "locoes" in a corral will frequently form in single file and follow the fence from corner to corner around the enclosure many times.

A locoed horse exhibits many symptoms showing poor muscular control. His walking is slow and labored, his head at the same time moving up and down to an exaggerated distance. While standing still, his head hangs lower than is normal. He raises his feet slowly and very high in stepping over obstacles in his way. Flexion seems to be more difficult than extension. There is an increasing tendency to stumble. The animal when lying down gets up like a cow on the hind legs first. The hind legs are not so much affected in the horse. A slight tendency for the feet to be placed too widely apart, especially the hind feet, the right from the left, is noticeable in the last stage of the disease. The horse has occasionally to catch himself from falling while merely standing still. He cannot back up but if one tries

to make him do this he will rear up and fall over backwards. Later in the disease, instead of rearing up this way he will simply run straight ahead when anyone tries to make him back up by whipping his nose.

In some cases the lips will quiver excessively while the horse is drinking. The eye appears somewhat glassy from an excess of secretions. The urine in late stages of the condition is voided without extrusion of the penis, which is sometimes extruded a minute later.

POST-MORTEM EXAMINATIONS.

Some entirely new findings of the Department of Agriculture in the experiment at Hugo, Colorado, were confirmed by us, concerning the pathology of loco weed poisoning.

All of the horses when found dead were lying on the left side and the legs were at right angles with the body as they are when the animal is standing. The abdomen was not so soon distended by gas as is usual in the horse. There was no rigor mortis present save a very little in one hind leg. The hair was very rough and the animal in every case was very greatly emaciated. A small amount of amber-colored fluid was coming from the nostrils. This was a sero-sanguinous exudate of the mucous membrane of the nasal chambers, particularly that covering the turbinated bones. The eye next to the ground was closed, the other one being half open.

The organs of circulation were normal. The heart was normal in size and weight and the valves were all competent. A slight increase of the pericardial fluid could be noted. The organs of respiration were also normal except for congestion of the turbinated bones, with the exudate mentioned in the nasal chambers, and perhaps a slight excess of pleural fluid. The general condition of the abdominal cavity was good, the organs appearing normal or slightly pale. Here and there, along the intestines externally, or on the parietal peritoneum, might be seen an occasional small, slightly congested patch. The ali-

mentary canal was normal as far as the stomach, where the lining coat of the cardiac portion of the mucous membrane could be easily stripped off, the fundic or second portion was very badly congested amounting to an inflammatory process, and the pyloric or third portion of the organ was covered with a very great excess of mucus coming no doubt from the congestion of the fundus. This excess of mucus, altho not so great, was found all along the remainder of the alimentary tract, as were also many bots which had come from the stomach wall. Horse No. 3 did not show the congestion but the lining of the cardiac portion could be easily stripped off. The disease in this animal ran an acute course, which perhaps explains this. Bots were present in the stomach but many of them were loosened from the wall and many more were found loose in the intestinal contents. The stomach contents were very small in amount, except in the case of Horse No. 4, where the organ was enormously distended by loco weed, the stomach with its contents weighing $28\frac{1}{2}$ pounds. The contents looked normal save for the slight excess of mucus.

The intestinal contents appeared normal save for some excess mucus. In the case of Horse No. 2 the mucus was present in the small intestines in a very excessive amount, there being few or no other intestinal contents. In character this mucus was tenacious, yellowish-white and slightly frothy. The slight excess of mucus persisted thruout the large and small colons and the rectum, but the contents were otherwise normal.

The spleen in one case was normal, in another it had a greenish cast, and in still another, Horse No. 3, it was bright red in its posterior third, bluish-black in its middle, the rest being dark blue. The kidneys were normal or slightly pale, as were also the other abdominal organs.

The greatest change of all was noticed in the nervous system. This showed much congestion thruout. The extra-dural space of the spinal canal was distended very greatly by a transparent,

jelly-like exudate which was organized, having a cherry-red color due to the numerous tiny blood vessels running thru it in all directions. This exudate extended to the foramen magnum and was not adherent to either periosteum or dura but clung to the spinal nerves at their origin, since it ran thru and filled the opening between the anterior and posterior nerve roots in each case and was thus held in place by these. It was in greatest amount at the cervical region. In this region the exudate was a very deep red, becoming much lighter, almost a pink, in the dorsal region, while in the lumbar region it was scarcely more than a buff color or an orange-pink.

